BUILDING A WORLD CLASS INFRASTRUCTURE TO SUPPORT E-COMMERCE IN MALAYSIA

Raja Mohd Rosli bin Raja Zulkifli

ABSTRACT

As we move into the next millennium, the world is becoming increasingly borderless with producers finding themselves no more restricted to their traditional national markets. Rather, with the ubiquity of the Internet, anyone with connectivity to it is a potential customer. As the technology becomes more secure, we will see more and more commerce undertaken on the Internet namely, the advent of the digital economy. This paper attempts to give an insight on the requirements of e-commerce and then highlights on the infrastructure that TM already has in place for realising the government's vision of making the nation a regional e-commerce hub. It discusses the business value for the corporation to deploy the Intranet, Extranet and e-commerce infrastructure utilising the various infrastructure and services already in place namely COINS, TMNet and the forthcoming service from Telekom Malaysia, TMSecureNet, a shared private network multimedia utility service with plans for a global offering.

INTRODUCTION

The term "electronic commerce" has been used to describe all steps of the commercial process that is managed via computer and over the network. It encompasses everything from consumer-oriented virtual storefronts and malls, to business-to-business applications such as supplier or client "extranets" and EDI (Electronic Data Interchange) to behind the scenes business functions like electronic payment systems and order management.[1] It is inevitable that electronic commerce will play a role in our future and numerous applications, among them Pay-per-view TV, Internet commerce and digital cash/credit card convergence which are already being developed. The promise of electronic commerce is one of the major factors that is contributing to the rapid growth of the internet as a communications medium. In the past two years many of the businesses adopting electronic commerce are confused and worried by the threat of losing money through electronic pilferage or credit card fraud. As such, with any commercial activity, it is important to consider security implications of doing business in such electronic modes.

TM is aware of the developments and needs of e-commerce and therefore devising and tailoring its network offerings for e-commerce to become a reality. The focus of this paper is to describe an overview of Telekom Malaysia's public network solutions and highlights the level of network security technology behind each network solution in providing this secure infrastructure framework to support electronic commerce.

BACKGROUND

Description of E-Commerce

A proper description of e-commerce[2] would be: 'Electronic Commerce integrates communications, data management, and security services to allow business applications within different organisations to automatically interchange information. Communication services transfer the information from the originator to the recipient. Data management services define the interchange format of the information. Security services authenticate the source of information, verify the integrity of the information received by the recipient, prevent disclosure of the information to unauthorised users, and verify that the information was received by the intended recipient.

ISSUES IN ADDRESSING E-COMMERCE

A fully scaled, comprehensive national e-commerce capability, however, involves much more than just the reduction of paperwork and the speeding of decision or giving making information for business and government transactions. In particular, the creation of advanced infrastructure that can support national e-commerce requires solutions to many technical, legal, security, financial, and regulatory barriers, as well as the widespread adoption and use of a variety of technical standards for communications, information processing, and security.

To create a national e-commerce infrastructure, the following seven subject areas, illustrated in **Fig. 1** below must be co-ordinated and facilitated through public-private sector partnerships, setting base implementations and standards for minimising overall costs, but while allowing for flexibility to meet unique requirements such as:[3]

- Agreements among organisations of partners interchanging information on diverse subject-matters, so that the developed infrastructure meets all requirements in a cost-effective manner;

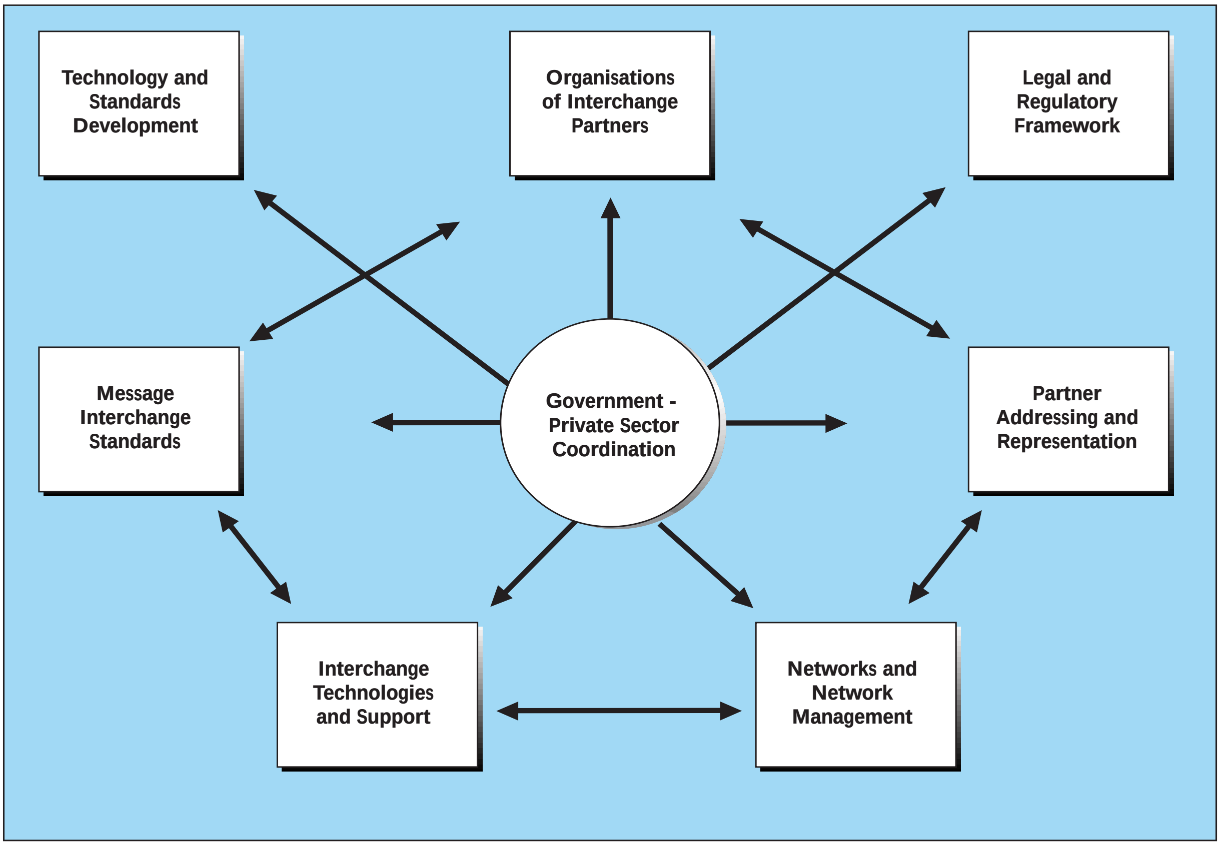

Fig. 1: Planning for a Global E-Commerce

- Details of message interchange standards;
- Supporting interchange technologies such as communications protocols, audit trails, security, and graphics interchange capability;
- Network reliability, availability, and management, including agreements among connecting networks, to assure that messages are delivered in a timely manner with integrity, security, and appropriate audit trails;
- Directories of prospective partner information, including network addresses and representational data, such as contacts for e-commerce, banking arrangements and financial terms for buying and selling, and sources for security credentials and public keys;
- Technology and standards development, including a national e-commerce architecture employing a distributed implementation using networks such as the Internet that tie together other networks, and transmit electronic mail, formatted commercial documents and graphics.
- Legal and regulatory framework, including strategies for facilitating the transition from paper-based commerce to e-commerce, and for addressing such issues as legal acceptance of electronic documents and electronic signatures, assurance of trustworthy electronic record and trusted third party transactions.

There are nine areas where international agreements are needed to preserve the Internet as a non-regulatory medium, one in which competition and consumer choice will shape the marketplace. Although there are significant areas of overlapping, these items can be divided into three main sub-groups namely:

Financial issues
- customer and taxation
- electronic payments

Legal Issues
- uniform Commercial Code for e-commerce
- intellectual property protection
- privacy
- security

Market Access Issues
- telecommunications infrastructure and Information technology
- content
- technical standards

The most crucial part for delivering e-commerce are:

- delivering telecommunications and IT infrastructure platform and

- security and privacy mechanisms as part of the infrastructure offerings adopted for realising secure e-commerce transactions

THE NEED FOR A NATIONAL INFORMATION INFRASTRUCTURE (NII) FOR E-COMMERCE

An advanced NII as part of the Global Information Infrastructure Framework (GII) for e-commerce is needed to support activities such as the following:

- Electronic Funds Transfer for executing and completing the procurement process between buyers and sellers with less financial risks and fewer errors, reducing paper handling and storage
- Government Regulatory data interchanges for collecting data from various communities to enable the government to carry out its mandated responsibilities.
- Collaborative Engineering
- Enterprise Integration extending integration throughout a company and into other trading partners.
- Computer Supported Collaborative Work with the intent to remove barriers (time, space, information complexity) that inhibit interactions among people.

SECURITY REQUIREMENTS FOR SUPPORTING E-COMMERCE

Global Information Infrastructure (GII) is the largest Information Infrastructure initiative by the US administration and world governments in supporting infrastructure for e-commerce gearing for a secure and reliable framework. The cornerstone of the GII is to create a Community of Global Interest compared to other smaller national initiatives of different countries (NII) that among them is Singapore ONE. If Internet users do not have confidence in the security of their communications and data are safe from unauthorised access or modification, they will likely not use this mode of business on a routine basis for commerce.

A secure GII thus requires:[1]

- secure and reliable telecommunications networks;
- effective means for protecting the information systems attached to those networks;
- effective means for authenticating and ensuring confidentiality of electronic information to protect data from unauthorised use;
- well trained GII users who understand how to protect data from unauthorised use and also how to protect their systems and their data.

There is no single magic technology that can ensure that the GII will be secure and reliable. Accomplishing that goal requires a range of technologies (encryption, authentication, password controls, firewalls, etc.) besides effective and consistent use of those technologies, all in turn globally assisted by trustworthy key and security management infrastructures.

One point of particular importance at this juncture is the development of trusted certification services that support digital signatures system that will permit users to know whom they are communicating with on the Internet. Both signatures and confidentiality rely on the use of cryptographic keys. To promote growth of trusted electronic commerce environment, the US administration is encouraging the development of a voluntary, market driven key management infrastructure that lends support to features of authentication, integrity, and confidentiality.

Accordingly, to ensure the healthy growth of global e-commerce over the Internet,due standards shall be needed to assure reliability, inter-operability, ease of use and scalability in areas such as the following:[1]

- electronic payments;
- security (confidentiality, authentication, data integrity, access control, non repudiation);
- security services infrastructure (eg. public key certificate authorities);
- electronic copyright management systems;
- video and data-conferencing;
- high speed network technologies (eg. Asynchronous Transfer Mode, SDH)
- digital object and data interchange;

TRANSACTIONS OVER THE NETWORK

Fig. 2 illustrates the typical components that make up an e-commerce framework today.

The basic requirements for conducting e-commerce shall include confidentiality, integrity, authentication, authorisation, assurance and privacy. The first four requirements for e-commerce can be solved by way of technology but the last two requirements,

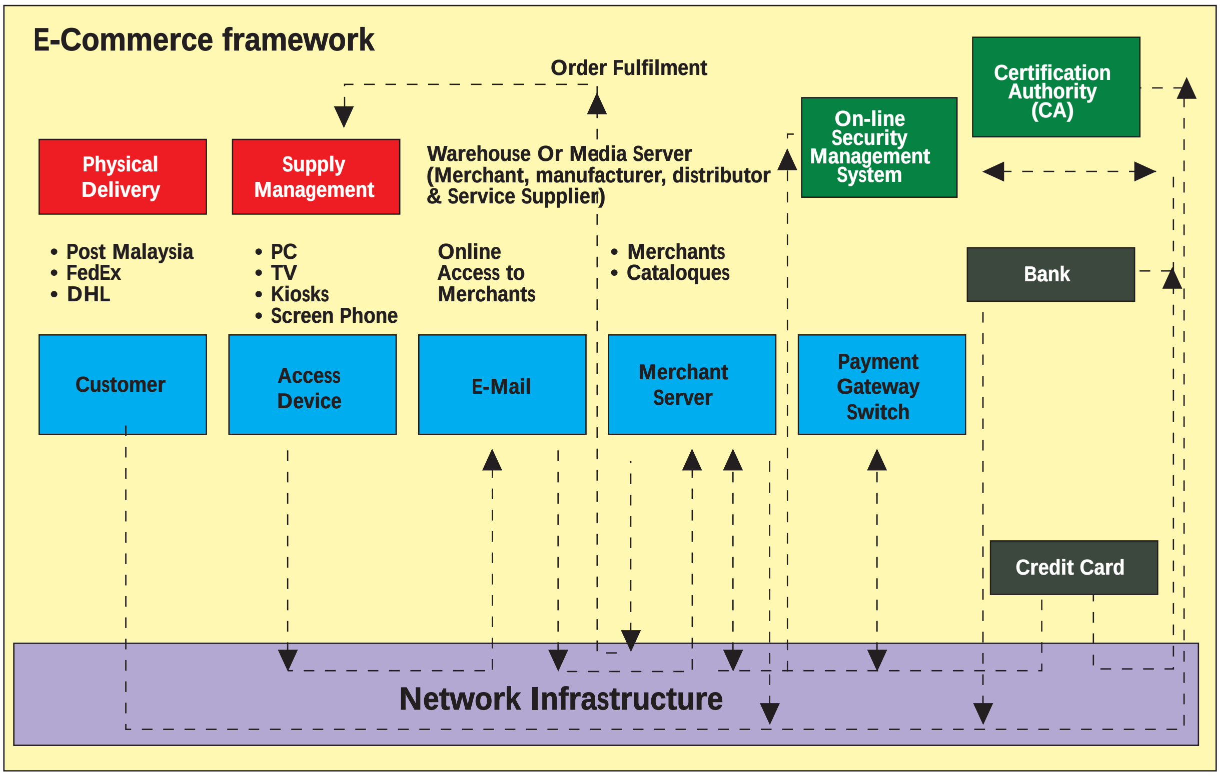

Fig. 2: E-Commerce Transactions over Network Infrastructure[4]

assurance and privacy, depend very much on the individuals and organisations acting responsibly like they do for their technological solutions. This includes adherence to laws that protect customers against fraud by merchants or similar participants.

Powerful authentication and encryption methods are realised by cryptography which does encoding of data and to authenticate networked individuals and computers for such things as Web-based transactions. In addition, cryptography includes special methods for digital identification of persons that can be transmitted over a network with messages or files, that are useful for authenticating messages and software. Cryptographic techniques offer three essential types of services for e-commerce; authentication (which includes identification), non-repudiation, and privacy.

In order to use public key cryptography, a public key and a private key are usually generated by a program that is going to use such key such as the web browser or e-mail program. However, distributing public keys is a problem and a better, trusted way of distributing public keys is to use a Certification Authority. A Certification Authority will accept the users' public key, along with some proof of the users' identity (it varies with the class of certificate), and serve as a repository of digital certificates.

While the Internet has implemented less security in the past than private value added networks (VANS), or corporate-nets, efforts to incorporate a variety of security mechanisms to Internet traffic has been moving ahead. It now looks as though the Internet has gained excess of riches pertaining to security, with a variety of standards covering many levels of networking, from physical packet level security, all the way to application level security.

Types of Electronic Payments

The methods that have been developed for making payments on the Internet are essentially electronic versions of the traditional payment systems we use everyday- cash, checks and credit cards. The fundamental difference between electronic payments systems and traditional ones is that everything is digital and is designed to be handled electronically. While many of the payment systems are currently implemented for use on personal computers, we will see other devices supporting them before long. Soon PDA (Personal Digital Assistants) will be used for handling payments and trials are already under way with smart cards.

The use of servers and browsers that support the SSL(Secure Sockets Layer) protocol only protects data against network monitors and spies. It does not guarantee that data is protected from spying eyes on merchants's end. To protect against merchant fraud (using a credit card for unauthorised purchases, for example), systems such as Cyber Cash, Verifone or First Virtual can be used. Cyber Cash and Verifone both use a helper application called a wallet for the

Web browser, and pass the encrypted credited card number through the merchant to its own processor/ server for authentication and approval of the sale. First Virtual issues a Virtual Pin in place of the credit card account number to clear the purchase. This justifies the case where the electronic versions of a traditional payment system offer an added advantage using encrypted credit card information with a third party, such as First Virtual or Cyber Cash, instead of allowing the merchant to handle credit card processing, offering more protection against merchantile fraud than is commonly seen in the everyday world.

SET

Significant standards are in the making which will make the interoperability of electronic wallet and credit card transactions simpler, both for consumers and businesses. The most popular is SET or "Secure Electronic Transaction" which is developed by a consortium led by MasterCard and Visa. SET is actually a combination of protocols designed for use by other applications (such as web browsers) and a standard (recommended procedures) for handling credit card transactions over the Internet. Designed for cardholders, merchants, banks, and other card processors, SET uses digital certificates to ensure the identities of all parties are involved in a purchase. SET also encrypts credit card and purchase information before transmission on the Internet.

Smart card applications

Although smart cards have been around for more than a decade, they have not seen widespread use. Pre-paid or stored value cards are currently in use in public telephones, toll booths and mass transit systems. The real impact of electronic commerce, especially tied to the Internet, come with the development of smart cards that include an embedded microprocessor. These smart cards will not only be used for internet-based purchases, but also to serve as electronic purses that can be used for everyday purchases at stores. The technology to support electronic commerce using smart cards is still being further developed by a lot of companies, and it is currently being field-tested on a limited basis. Mondex International (in which Master Card has a majority interest) is conducting one of the largest field trials in England. Mondex International's (in which Master Card has a majority interest) smart cards use digital cash system developed by David Chaum and DigiCash.

Smart cards have yet to make a significant impact on consumer markets, but the pieces to make that possible are now starting to be put in place, for example, Verifone a leader in POS hardware market for merchants has developed a low cost smart card terminal for merchants as well as a smart card reader that is linked to a user's PC. Personal ATM allows users to download money into a smart card at home.

TM INFRASTRUCTURE FOR REALISING E-COMMERCE

Having discussed the overview on feature elements that make up e-commerce, and along with its network infrastructure, TM has also incorporated its own security system in support of electronic commerce. There has already been a deployment in Telekom Malaysia the following back-up systems namely:

a) TM COINS (TM's Corporate Information Network Superhighway)

b) TMNet (TM's Internet Service Provider network)

c) TMSecureNet (TM's managed application server network)

With the combination of these three networks, e-commerce applications can be accessed by practically everybody from anywhere nation-wide or world-wide and the most ubiquitous means of access is through TMNet, combining it with the security and reliability features of COINS which have nationwide and global connectivity coupled with the added security by TMSecureNet for global connectivity at the middleware/applications layer for virtual private networks accessing intranet and extranet services. **Table 1** shows the strengths of these network offerings.

Network Offering	Strength
1. TMNet	Provides universal accessibility to any end user via a normal dial-up connection
2. COINS	Provides complete end-to-end network management and solutions with robust built-in security
3. TM SecureNet	Provides end-to-end security and manageability of application servers/ middleware for desktop-to-desktop customer applications and solutions

Table 1: Strengths of network offerings

These infrastructure services built on top of each other and bundled together will ensure a winning combination as the foundations for realising a secure and reliable e-commerce infrastructure.

TMNET

TMNet is the name for Telekom Malaysia's Internet Service Provider Network. TMNet and other ISPs throughout the world are interconnected to form a global internet network. TMNet is made up of a centralised data centre, distributed Point-of-Presence (POPs) and a Gateway to other ISPs. The components are connected locally via a highly secured Corporate Information Network (COINS). TMNet has 24 POPs throughout Malaysia. POPs function as access points or sometimes called nodes to TMNet. POPs are distributed strategically nation-wide and will provide users with convenience and economy by dialling in or connecting to the nearest POPs. The backbone provides the high- speed connectivity from all the POPs to data centre as well as internationally to other ISPs. TMNet is riding on Corporate Information Superhighway (COINS) for nation-wide backbone connectivity.

- TCP/IP protocol and UNIX can be easily manipulated
- existence of re-mailer servers (where addresses can be made untraceable)
- communication can be listened/sniffed
- unauthorised entry/access and unauthorised transactions
- unauthorised disclosure of information
- destruction/ modification of information
- virus threat

To address these Internet security concerns, TMNet has adopted the following measures:

i) Install Firewalls (routers which separate internal network from external networks) which make use of encryption for private Information (private/ public key) to prevent unauthorised listening or sniffing;

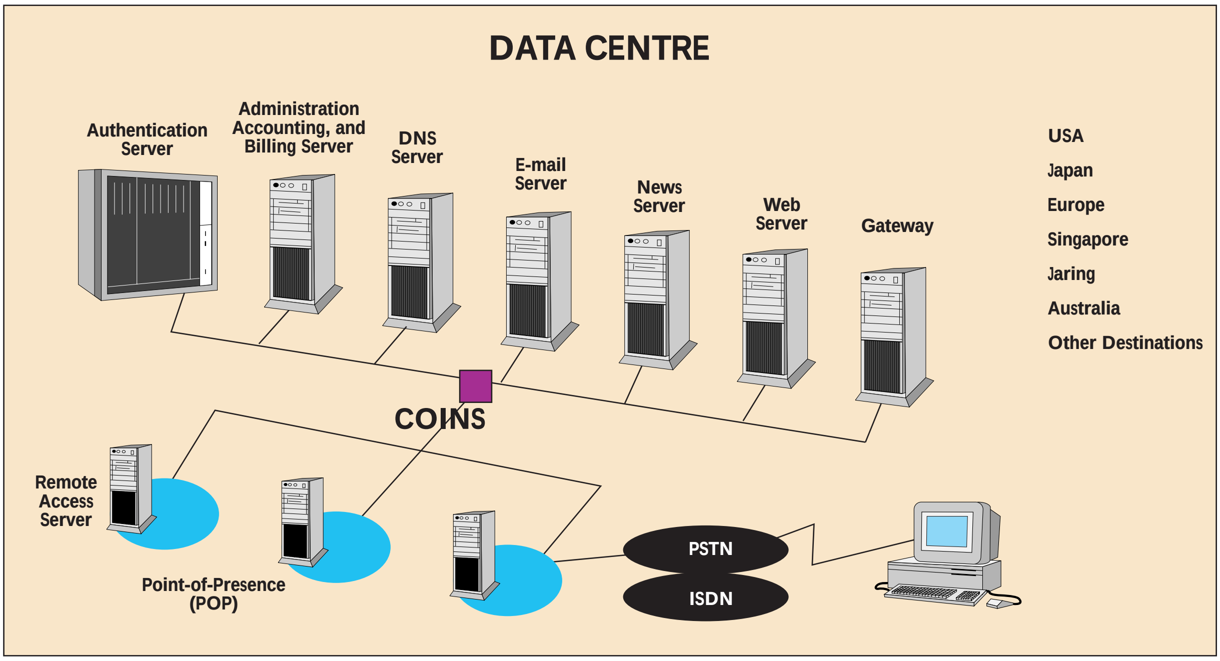

Fig. 3: TMNet backbone connectivity via COINS

How TMNet addresses the security concerns as part of ensuring secure transactions on the network for widespread access to e-commerce:

Performing the role as a widely available and ubiquitous access to e-commerce infrastructure and other networks, TMNet must address the following security issues or threats:

- there are too many users on the internet which are interconnected to so many networks

ii) Make use of innovative authentication(regular change of ID/passwords) to prevent masquerading;

iii) Segment authorisation to access i.e. different ID/ password for different levels of access to prevent unauthorised transactions or change of information;

iv) Install frequent audit trails to check and record unauthorised access and logs, enforce regular monitoring and administration to ensure the best security techniques and strategies are employed and;

v) regularly screen for viruses and install backups/ redundancy for important components to prevent loss of crucial data

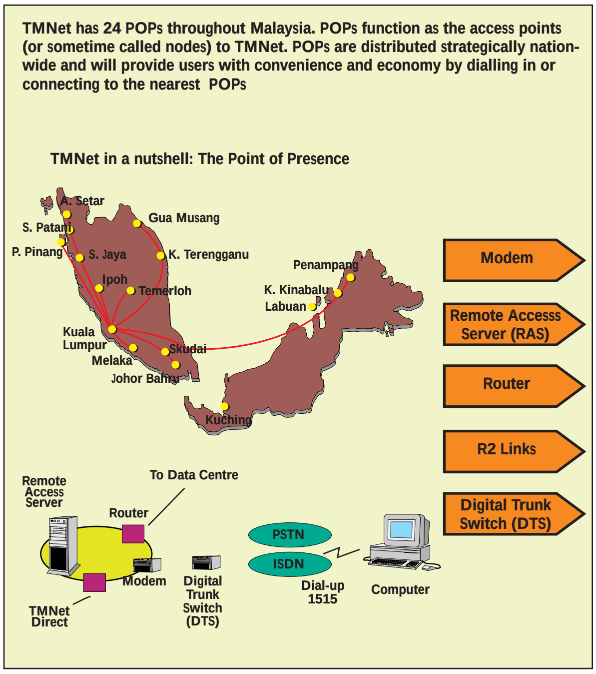

Fig. 4: TMNet nationwide coverage

TM COINS NETWORK

COINS-A fully Managed Secured Network solution for end-to-end connectivity

COINS or Corporate Information Superhighway, is a fully managed high speed network for end-to-end connectivity. It is a globally connected nation-wide broadband communications network which supports multimedia applications, networked computing and communications. COINS is a fast, open, multimedia network with a huge capacity of up to 10 gigabits per second.

As Malaysia moves towards the realisation of the Multimedia Super Corridor (MSC), new business challenges will present themselves. Among them are regionalisation and globalisation of business, remote manufacturing, borderless marketing, e-commerce, distance-learning, to name a few. By virtue of its broadband multimedia applications, COINS is the only networking solution that can meet these demands. The leading edge features of COINS that provide maximum user benefits are multi-tiered network architecture; total inter-networking; new applications; bandwidth-on-demand and total networking solutions.

Besides being the most advanced, fastest, multimedia network, COINS offers users the most of value added[5] services namely:

i) Private Virtual Circuit (PVC);
ii) Virtual Private Network (VPN);
iii) Virtual Private Dial-up Network (VPDN);
iv) Bandwidth-on-demand;
v) Wide Area Network (WAN) management;
vi) Support for back-up and recovery;
vii) Internet gateway;
viii) Multimedia Super Corridor (MSC) gateway
ix) Consultation on the design, implementation and migration strategy of the network.

Security features of COINS for reliable E-Commerce

COINS adopts various security mechanisms at various layers using cryptography and encryption for its VPN, VPDN access, its firewalls and Smartcard / SecureID system. Details of the encryption mechanisms employed at various levels is provided in **Fig. 5**:[6]

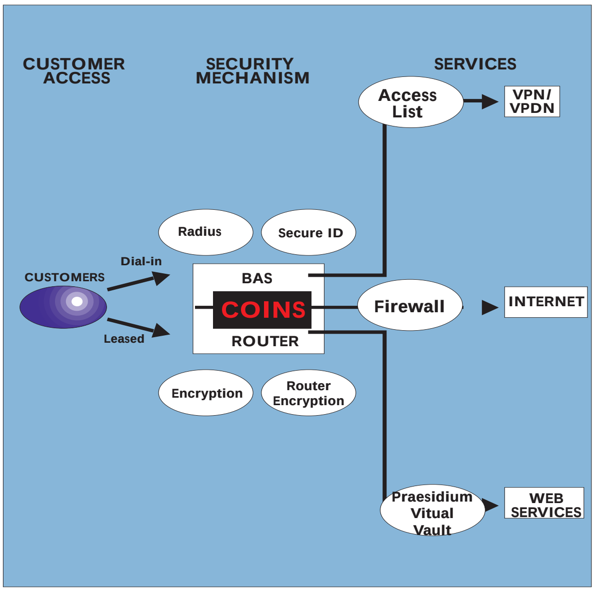

Fig. 5: COINS Security Mechanism

Virtual Private Network (VPN) Security

COINS Virtual Private Network (VPN) is a managed, Wide Area Networking (WAN) solution that supports secure and reliable internal communications and widespread sharing of information. These customised solutions typically support internal communications within large enterprises and among partners and suppliers. COINS VPN is the only secure, encrypted data networking solution that provides an un-paralleled site-to-site managed service as pre-established Service Level Agreements. Security mechanism employs end-to-end encryption which provides user authentication, and encryption at both level 2 (Ethernet) and level 3 (IP) layers while ensuring protection against eavesdropping, modification of data, masquerading and access control. Separation of Interne from Intranet is implemented by compartmenting the O/S into two areas with separate LAN cards where the Trusted Gateway Agent (TGA) performs transactions on behalf of the Internet client.

To ensure further security in the prevention of Web Server spoofing, the web server is authenticated by a Certification Authority (CA), and secured online access to Web-based applications are enabled so that customers can log problems using Trouble Ticketing system and view Virtual Private Network performance report thus ensuring confidence on their data integrity.

Security on Proxy/Firewall

Proxy and firewalls are routers which separate internal COINS network from external network. Security features supported on Proxy and firewalls are the examination of TCP/IP based connection attempts in and out, allowable/ denial of each attempt based on authorisation rules, defined, and provides support for smart card authentication mechanisms such as SecureID and S/key using one time passwords to enhance security.

Virtual Private Dial-up (VPDN) network Security

COINS VPDN is a fully managed, high speed, dial-up network solution providing secure access to corporate information. With COINS VPDN, corporate information is accessible just about anywhere, anytime. For supporting VPDN security, COINS make use of Radius (Remote Dial-in) ACE authentication server which provides user authentication using triple DES/IDEA cryptography algorithm; accounting record of users logging information to generate billing data and auditing record which allows tracking and monitoring of user connectivity.

TMSECURENET

Telekom Malaysia has already built a private TCP/IP network called TMSecureNet with major nodes across the country. Corporations and their branches as well as partners can connect to the nearest node. This will be beneficial for the corporation because TMSecureNet is able to provide faster deployment, greater scalability, cost effective management and easy administration backed-up by first-rate customer care services.[7]

TMSecureNet is built on Telekom Malaysia's COINS (Corporate Information Network Super Highway), an ATM-based Wide Area Network, with firewalled connection to TMNet as shown in **Fig. 7**. Access into TMSecureNet will be via dial-up, ISDN and frame relay. There are plans to enable GSM and pager access in the future. This means that customers of TMSecureNet will be connected to a private broadband network with connectivity to the Internet market not only in Malaysia but also to the rest of the world. Today TMNet is a member of a roaming consortium which include key Asia Pacific countries,

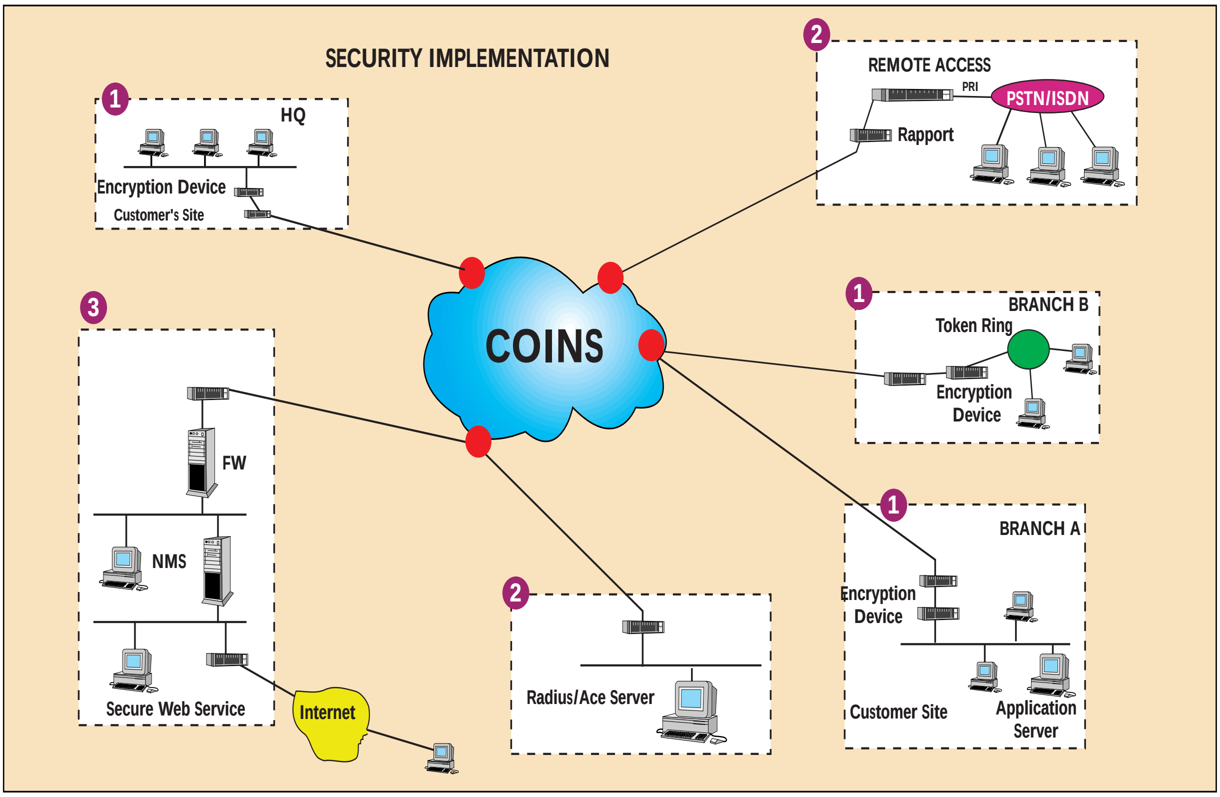

Fig. 6: COINS Security Implementation

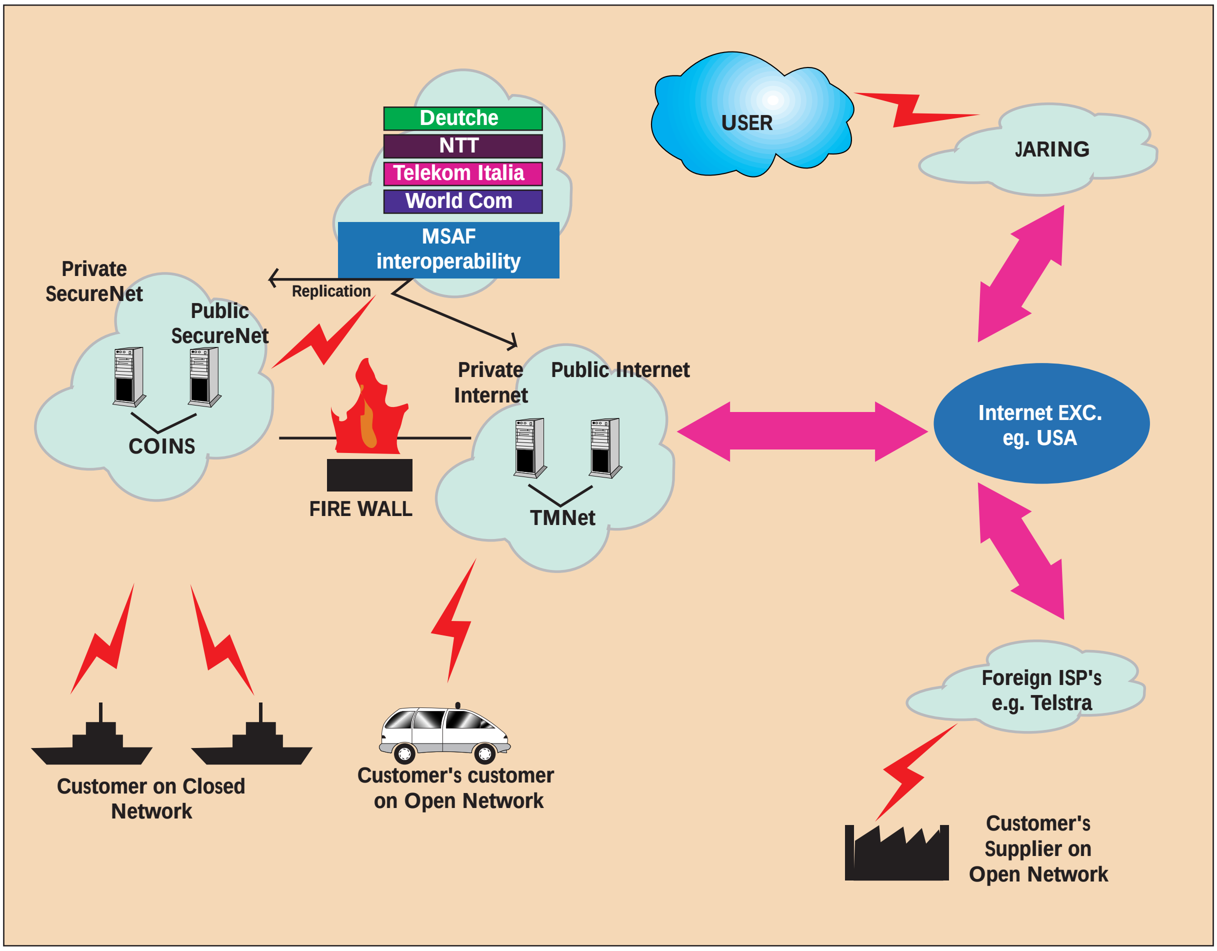

Fig. 7: TMSecureNet-typical Service Architecture

European countries and the US as member countries. Customers of TMSecureNet travelling in areas covered by member ISPs can enjoy local call access into the ISP for their corporate information.

Link Between Intranet, Extranet and E-Commerce is Security

Whilst the intranet, extranet and e-commerce address different business requirements they nevertheless hinge upon the crucial issue of security. For e-commerce there must be three pre conditions before a transaction can take place i.e. authentication, encryption and non-repudiation.

Authentication mechanism ensures that the person who attempts to log-in is who he says he is. On the other hand, encryption scrambles the information communicated over the network to ensure that only the intended receiving party is able to decipher the information. In non-repudiation, the use of digital signatures ensures that neither of the parties in any communication session can deny that they ever communicated .If both the corporation's intranet and extranet satisfy these conditions, then it can be assured that it is operating in a secure environment.

SecureNet is not just a highly secured cordoned private TCP/IP network. At a higher service layer, it can be viewed as a utility service whereby if in the past the telephone comes with the telephone subscription, today TMSecureNet will come with standard off-the-shelf intranet and extranet applications. In between the network and application is also a whole set of glue middle-ware services e.g. Certification Authority and other e-commerce enabling services. As a total solution it will offer three preconditions for e-commerce i.e. authentication, encryption and non-repudiation. It will offer secure services at both the network and application levels. Delivery of this service will leverage on the best-of-breed technologies with the best of partners both locally and from abroad to be identified from time to time.

TMSecureNet with Lotus Notes

Telekom Malaysia plans to offer TMSecureNet with Lotus Notes which will bring to reality an interoperable Lotus Notes Global Public Network Service. This is being achieved through Telekom Malaysia's membership in the Multimedia Services Affiliate Forum or MSAF, New York which is a grouping of global Telcos and ISPs in the business of inter-operating multimedia services globally so as to ensure secure and high level of service for corporations to do business on the Net or networks with TCP/IP protocol. This one-stop service system will see Forum members inter-operate within an agreed framework which covers service quality, inter-carrier settlement and other seamless commercial arrangements.

Security Features of TMSecureNet

The Application Layer which is visible to the customer sits on top of the network layer. In order to access TMSecureNet hosted applications, customers can come from two types of networks, the open network or the close network.

Open Internet means the customer will choose his own ISP to get connected, while for closed network, servers are placed behind firewalls. For the closed network, TMSecureNet is using COINS. COINS offers an optional service where data to be transmitted is encrypted.

The customer, whichever network he chooses to use the service, will then encounter the application layer. In this layer, TMSecureNet offers an option that enables secure transaction to be established between the network client. TMSecureNet manage their servers utilising RSA technology. This in effect establishes a Public Key Infrastructure (PKI) much needed for the extranet and business-to-business commerce. Today this option consists of servers leased from TMSecureNet together with Lotus Notes clients installed on PC end users.

In the near future, as a Certification Authority (CA), TMSecureNet will allow the customer to use any web browser to securely transaction with TMSecureNet managed servers.

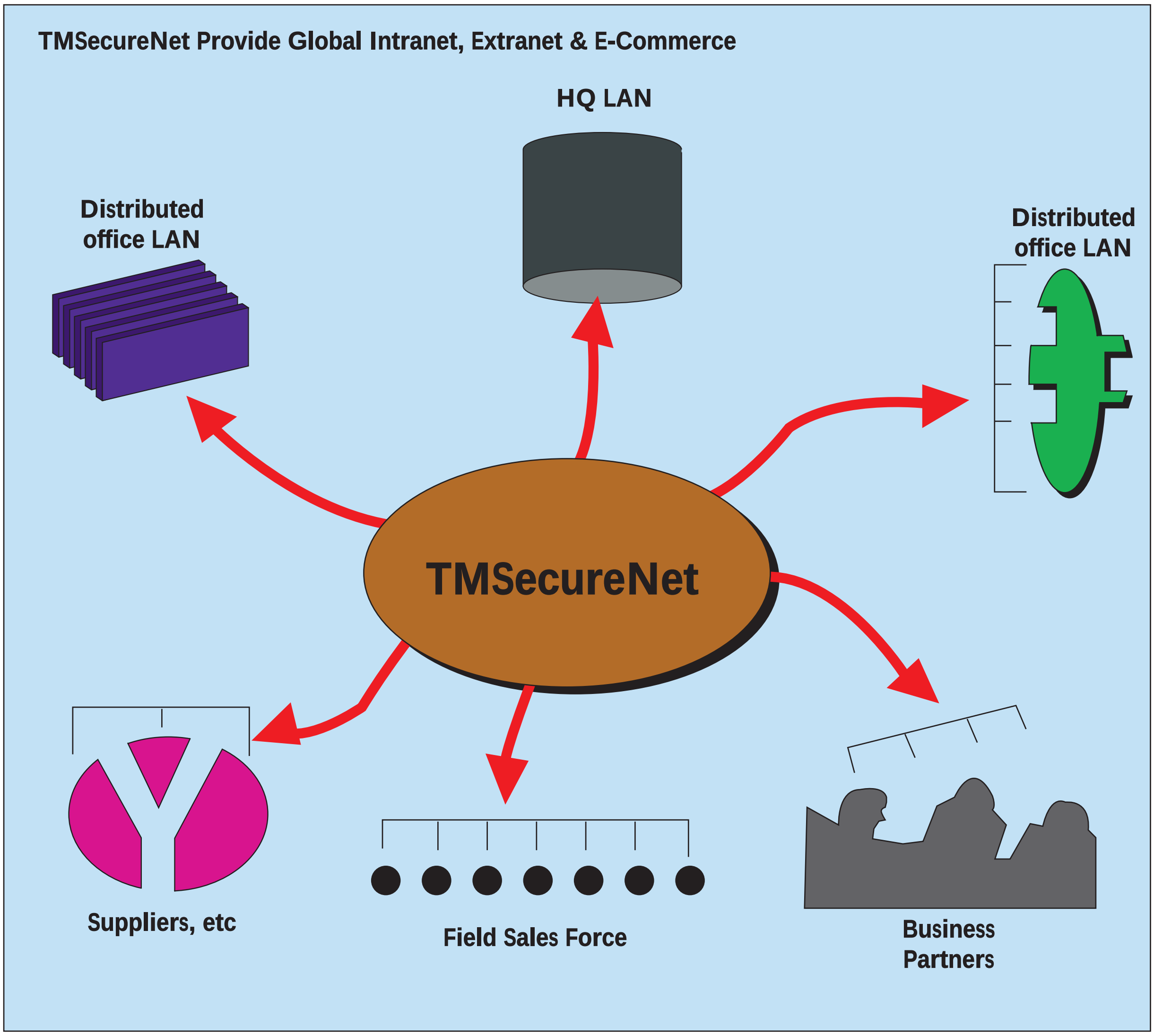

Fig. 8: TMSecureNet provides Global Intranet, Extranet and E-Commerce

THE FUTURE OF E-COMMERCE

When real e-commerce happens

Many different institutions, industries, and other parties with vested interests will affect the progress of e-commerce. This can be depicted as in **Fig. 9**.

Technologies for realising e-commerce is still evolving at a rapid pace especially in the area of crypto-systems and public key algorithms. The current key length allowable for export by the US government is restricted to 512 bit key length. New evolutions towards this could be the use of far more sophisticated techniques using 2,048 bit key algorithms utilising local technology which have a promising future for the national e-commerce. Other components for realising more secure e-commerce transactions on the network will also need to be in place such as Certification Authorities as already discussed above. In future the element of trust is to be managed by a neutral third party (centres of trust). With such initiatives like eTrust who are attempting to certify trusted merchants on the Internet, other organisations are expected to join the to eTrust in due course. Other developments, though still in its infancy are micro-transactions, cyber-mediaries and software agents or 'knowbots' which roam the internet on behalf of the consumers are also being developed.[8]

In Malaysia, the Digital Signature Act 1997 will come into effect once the Government establishes the framework in two months time thenceforth. The act which is one of six cyber laws designed to facilitate e-commerce, will enable businesses and the public to use electronic signatures instead of their hand-written alternatives counterparts in legal and business transactions. The framework will define the various details to regulate digital signature Certification Authorities (CA). The public key infrastructure (PKI) is a driven world-wide market which is expected to be worth an estimated US$200 billion by the year 2000. By that year, potential market for certification authorisation in Malaysia with national root status will be about RM 194 million. The success of e-commerce is being eagerly awaited for a more secure MSC flagship in borderless marketing.[9]

In summary among the most pertinent issues needed for widely realising e-commerce is to have more of the following infrastructure components:

- National Public Key Infrastructure Implementation
- Federal Certificate Authority and Liability and Policy
- Good Security Practices for e-commerce
- Digital Signature Standard (DSS) which is critical to the success of e-commerce.

The future of e-commerce will be exciting and full of opportunities.

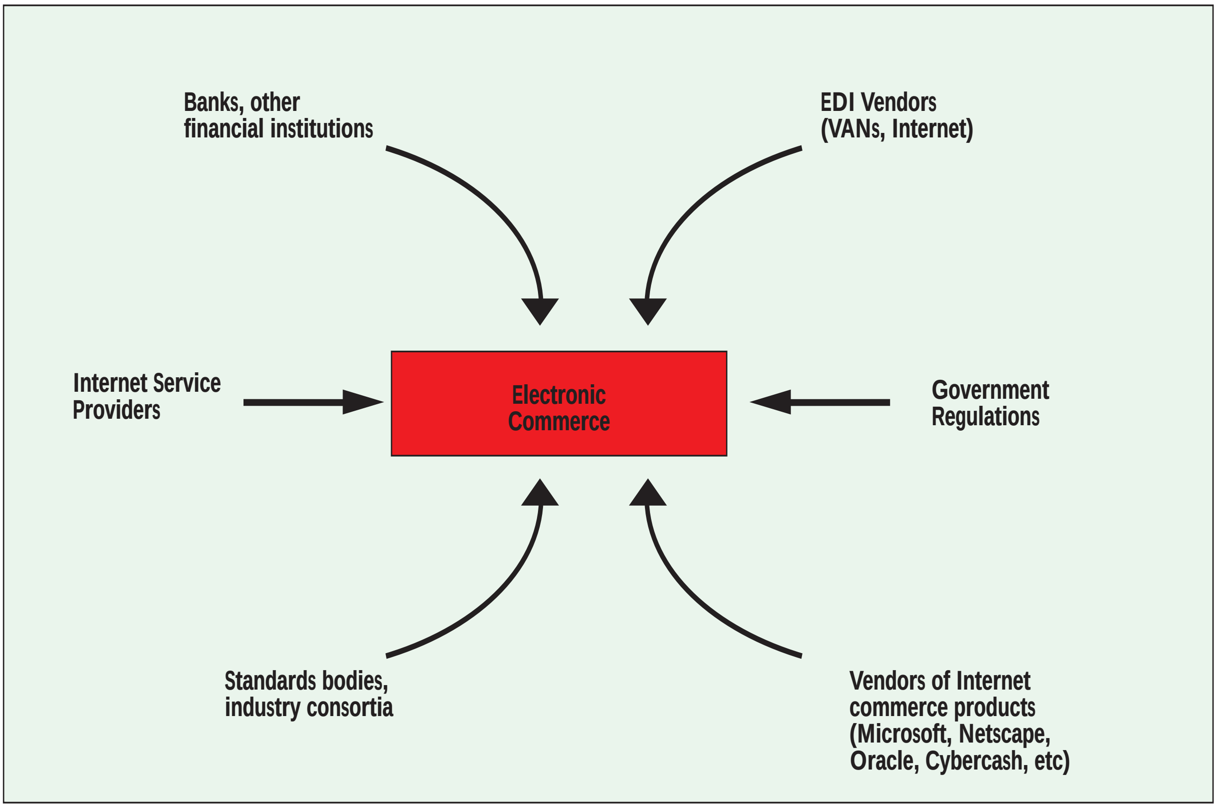

Fig. 9: Players determining the success of E-Commerce

CONCLUSION

The evolvement of e-commerce is very dynamic and the right infrastructure and components must be ready to support its explosive growth. Telekom Malaysia as the premier telecommunications provider in Malaysia has already in place the necessary infrastructure to effect e-commerce through its TMNet network, COINS and TMSecureNet Network as well as value added solutions through its smart card initiatives and through its subsidiary like VADS in the field of EDS. The continuous efforts by Telekom Malaysia in building and upgrading networks and infrastructure while catering for the necessary requirements of e-commerce in particular especially security, will serve as a reliable and future proof platform to catapult the nation towards realising the platform for a Global Framework of e-commercee.

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BIOGRAPHY

Raja Mohd Rosli bin Raja Zulkifli has been in Telekom Malaysia for 16 years and is now the Head of Network Specialist Group, TM Multimedia. Prior to this he has been attached at the TINA-Consortium Core Team at Bellcore Research Facility Red Bank, New Jersey, USA from October 1996 to December 1997 as part of the collaborative effort with 40 major companies consisting of telecom and software vendors. His major contribution to the Consortia work was as the author of Network Resource Information Model (NRIM) and the Network Component Specifications and numerous related validation work of the TINA specifications. Prior to that he was senior assistant manager, Switching and Manager for Non PSTN services in Network Strategy and coordinator for TM's involvement effort in joining TINA-C. He obtained BSc in Electrical/ Electronics Engineering from Nottingham University and MSc in Data Telecommunications and Networks, Salford University, Manchester in 1993. Having joined Jabatan Telekom as an engineer in 1982, he has wide experiences in telecommunications through working in the central region as well as southern region in the field of switching, long lines as well as local networks.

WHAT DOES ATM OFFER OVER ETHERNET? MAXIMIZING NETWORK PERFORMANCE THROUGH INTEGRATED BROADBAND TECHNOLOGIES

Mohd. Noah Mohd. Salleh

ABSTRACT

The increasing use of multimedia and interactive applications means that today's networks must not only move data faster, they must also move towards achieving consistency in the rate of data movement so as to ensure sound and video are not interrupted. Network managers today are concerned about achieving performance boost on their networks as well as some amount of Quality of Service or QoS on an end-to-end basis. This paper looks into the QoS requirements of multimedia and other services, into what is required of todays Local Area Networks (LANs) for supporting these services, into some of the QoS solutions that are available now, what benefits can offer over Ethernet and would it be cost effective to provide ATM to the desktop of today.

INTRODUCTION

Multimedia applications have raised new demands on computer environment, especially in terms of communications, due to the complexity and diversity of data which must be handled. A variety of different and often contradictory requirements must be satisfied. Isochronous data streams from live video and audio signals require high bandwidth, in-time delivery and low delay variation (jitter). However it can accept small amount of bit errors. On the other hand asynchronous stream which results from the transmission of still images or textual documentation needs reliable or lossless transmission but can accept small delay.[1]

Modern applications such as teleconferencing, distance learning and training, visual simulation and World Wide Web require accessing and displaying rich content consisting of text, graphics, audio/video and animation. Predictable Quality of Service (QoS) in terms of controlled response time and guaranteed bandwidth is increasingly important.

QUALITY OF SERVICE ON LANS

Unlike traditional data or telephone networks, future multimedia networks will provide multiple services, supporting not only voice and data but also new applications that require real-time performance guarantees and have variable bit-rate traffic characteristics. Integrated services networks must be designed to meet the stringent QoS requirements of multimedia applications such as real-time video, scientific visualization, telemedicine, etc, without being wasteful of valuable network resources such as bandwidth and buffer space.[2]

What is the definition of Qos? QoS is an objective measurement used to quantify the quality of a service being rendered to users. QoS is based on the underlying system or network design and it specifies the requirement of a service being carried on this system for it to achieve the desired quality. The design of this system is normally based on either a loss system or a waiting system and QoS attempts to make sure that enough resources are available in the system to support the requirements of the service. Putting it in the multimedia perspective, QoS encompasses various levels of bandwidth reservation and traffic prioritization for multimedia and other bandwidth intensive applications. What this means is that the network will have enough resources to not only support a particular service but to also guarantee that the service quality is of that agreed between the user and the network provider.[3]

Why is QoS important? To improve the quality of multimedia data transfer, QoS solutions minimize latency and jitter. Latency is defined as the time between transmission transmitted and receipt of data. Unpredictable and varying latency periods causes jitter. Jitter will in turn cause jerky video, garbled audio and erratic performance. To reduce this problem, we have to minimize jitter and to do this we need to regulate the timing of latency periods so as to ensure the smooth continuous predictable data stream for real-time audio and video solutions.Thus we need QoS solution.

Who needs QoS? Various applications have different QoS requirements. The necessity of QoS solutions depends heavily on personal preferences and specific applications:

- For voice communication, echo cancellation is normally required if the delay is more than 15 ms. Packetized voice can accept almost 1% packet loss rate without being objectionable to most listeners.
- For video application, the requirements depend upon several factors such as video coding algorithm, degree of motion required in the image sequence and resolution required for displaying the image. Loss will generally cause some image degradation which ranges from distorted image

to loss of entire frame. Also delay variations in the range of 20 to 40 ms can cause jerkiness in the video playback. Combined audio and video application is very sensitive to differential delays. Human perception is highly attuned to the correct correlation of audio and video.

- Users of interactive services are also sensitive to loss and variations in delay due to re-transmissions and inconsistent response times which can decrease productivity. This can affect how users perceive data service quality.

- Distributed computing and database applications can be very sensitive to absolute delay, loss and delay variations. The ideal environment for these types of applications is infinite bandwidth with latency close to that of the speed of light in fibre.

Based on the above arguments and on the fact that network applications can be characterized in two dimensions: batch versus real-time and one-way versus two-way (interactive), the requirements for QoS for different applications can be characterized in **Table 1**.

Based on the above table, it can be generally concluded that QoS is not required for batch applications whereas real-time or time-sensitive applications do require QoS.

Another important point to note is that QoS is a measurement which is best defined on an end-to-end basis. This is a much more meaningful perspective from the view point of the end user.

How can we guarantee an end-to-end QoS? The following section will discuss the comparison between Ethernet and ATM with respect to the capability of each in providing end-to-end QoS solutions.

ATM VERSUS ETHERNET

Ethernet, originally developed in the early 1970s, is basically a connectionless, broadcast- and collision-oriented, and packet-based. Most of Ethernet networks today require routers to effectively segment the networks to avoid overloading. It has evolved from being a shared medium technology to dedicated or switched technology providing speeds ranging from 10 Mbps to 100 Mbps to the desktop.

It is widely accepted that Ethernet does not have the capability to support QoS on an end-to-end basis. Numerous studies have been carried out in determining the maximum throughput that is capable out of an Ethernet network. With its underlying technique of using CSMA/CD or Carrier-Sense Multiple Access with Collision Detection as the main protocol for users on the Ethernet to talk to each other, the maximum throughput achievable is only 50-60% of the available bandwidth. Putting on more traffic than that will cause collisions to occur on a frequent

Batch	Applications	Required QoS
One-way	File transfer Imaging Simulation	Little or none
Interactive	Exchange text e-mail Internet browsing with audio/video	Little
Real-time	**Applications**	**Required QoS**
One-way	Broadcast video Distance learning Surveillance video	Various QoS levels
Interactive	Video/audio conferencing Process control	High QoS levels

Table 1: Requirement for Qos for different applications

basis and this in turn will cause severe congestion in the network. For Ethernet to support real-time multimedia applications, some sort of traffic prioritization and deterministic access is required.

How does ATM solve this QoS problem? One of the primary attributes of ATM is its capability to support voice, data and video traffic integration with guaranteed QoS for each type of traffic. This is basically done through ATM virtual connections which allow bandwidth and connectivity to be flexibly and dynamically allocated. In effect, ATM's connection-oriented nature provides inherent QoS. Because of this ATM is capable of supporting multiple QoS classes for different application requirements on delay and loss performance. In addition to this, ATM also offers enhanced delivery options such as point-to-multipoint and broadcast. ATM supports the following QoS for different traffic classes as defined by the ATM Forum as shown in **Table 2**.

bandwidth allocation prior to the transmission of data. This technique is particularly used in enhancing the IP capability to carry multimedia traffic.

TCP/IP is the most widely used protocol that is currently running in the networks of today and it will continue to be so for many years to come. However, IP is not designed to carry real-time traffic with its inherent latency problems. Two new protocols have been developed to help alleviate this problem.

Resource reSerVation Protocol or RSVP along with Real-time Transport Protocol or RTP facilitates transmission of time-sensitive data, enabling a regular IP network to run audio and video. Because IP networks are connectionless, they cannot predict paths taken by the data and hence to reserve resources. RSVP and RTP work hand-in-hand to provide the QoS and bandwidth required.

QoS class	QoS parameters	Service class	Applications
0	Unspecified	-	Best effort
1	Specified	A	Constant Bit Rate (CBR)
2	Specified	B	Variable Bit
3	Specified	C	Connection-oriented data
4	Specified	D	Connectionless data

Table 2: QoS classes

WHAT QOS SOLUTIONS ARE AVAILABLE NOW?

There are basically three solutions to the QoS problem. First is the enhancement to the Ethernet technology, second is enhancement to the TCP/IP protocol stack and third is ATM.
One of the enhancements to Ethernet which is being pursued currently by the IEEE organization is the 802.1p standard or the technique called traffic class expediting and dynamic multicast filtering. 802.1p is an extension to the 802.1d standard. This extension involves the addition of a traffic class and dynamic multicast filtering to define a priority standard for running multimedia voice and video traffic over bridged LANs. 802.1p allows network interface cards to communicate with switches to determine switch multicast filter settings. Frames traversing the Ethernet are classified into two priorities - time/safety-critical traffic and non-time-critical traffic. Traffic classification is carried in the frame or looked up in a filtering database.

Apart from enhancement to the underlying Ethernet technology, another method for providing QoS solution is by reserving network resources or

RSVP,[4] a proposed Internet Engineering Task Force (IETF) standard, allows TCP/IP based applications to request reservation of resources along the path of a data flow so that applications can obtain predictable QoS on an end-to-end basis. In an integrated services Internet, routers and end-systems will cooperate to provide different levels of QoS guarantees. To meet the goal of providing end-to-end QoS guarantees, all the hops along a data flow path must support reservation of resources and build firewall protection among competing data flows.

There are four levels of QoS offered by RSVP:

- The first is called guaranteed delay (equivalent to ATM's CBR service) which specifies a maximum delay across the network for real-time applications;

- Second is controlled delay (ATM's VBR service) which provides three levels of delay control;

- Third is predictive service which offers three levels of bounded delay, and guaranteeing no more than a specified maximum delay. This is suited for applications that can tolerate the late arrival of some packets; and

- Finally is controlled load which gives best-effort service over an unloaded network (ATM's UBR service).

RTP[5] on the other hand is a streaming-oriented protocol with a packet header for real-time transport. It addresses the latency and multicast problems of real-time traffic over IP networks. Together with RSVP which helps prioritize traffic when bandwidth is limited, these two protocols bring enhancement to the TCP/IP protocol stack to allow it to carry multimedia traffic.

One key feature of these two new protocols is that they can only run on IP networks. And for IP networks to support the addition of these protocols, the network elements such as routers must be upgraded. This could be through via simple software upgrade s but most of the time this upgrade requires extensive hardware changes.

As was discussed previously, ATM's connection-oriented nature provides inherent QoS. ATM is designed to deliver data with set, predictable timing. It enables applications to define bandwidth and service characteristics required for a transmission. Before traffic can flow in an ATM network, a virtual circuit (VC) must be created. A request for a VC normally comes with a request for QoS parameters (as defined for ATM) such as minimum bandwidth, maximum delay, delay variation and type of service. The network automatically allocates the resources required to guarantee the requested QoS. If there are no resources available to achieve this, the network rejects this request or offers a lower level of service. Apart from its capability of supporting time-sensitive traffic, ATM also offers enhanced delivery options such as point-to-multipoint transmission and eventually broadcast. Eventually the system might be further enhanced for instantaneous broadcast.

CONCLUSION

With all these QoS solutions available what will be the best network implementation? Network managers entrusted with the successful implementation and day-to-day running of their respective enterprise networks must balance the trade-offs between costs, complexity, migration paths and QoS. This balancing act is further complicated in a rapidly changing networking industry.[6]

Some of the key cost factors which warrant attention when deciding on the design of a network are network cost per desktop, practical average bandwidth per desktop, practical maximum bandwidth per segment, round trip latency and cost per Mbps per desktop. Other factors would be application requirements and profile of the users.

ATM is a very promising technology but most of the discussions about ATM in the local area network arena is usually focused on the application of ATM to the network backbone. This is because early implementations of ATM in LANs had been in the backbone. This is quite a normal approach in providing a migrating path as ATM in the backbone would complement the high performance LANs that are available today. Coupled that with the other QoS solutions such as 802.1 p and RSVP/RTP, QoS on an end-to-end basis to the users could be provided.

However getting these IP protocols to work on top of ATM would mean that ATM must efficiently carry IP traffic. ATM and IP naturally do not complement each other primarily because one is a connection-oriented protocol while the other is connectionless based. This mismatch has led to complexity, inefficiency and duplication in attempting to apply ATM technology to the LANs.[7]

Various approaches have been taken or are still underway to implement IP over ATM. Some of the solutions today are Classical IP over ATM or IETF's RFC 1577, LAN Emulation (LANE) and MultiProtocol Over ATM (MPOA) both from ATM Forum. All of these approaches attempt to bridge the gap between ATM and the end-users desktop. By having ATM all the way to the desktop, its full potential in the LAN can be realized. Nevertheless the puzzle would not be complete without the applications at the end systems that have the capacity and capability to control the network connections directly and having an active participation in the QoS negotiation. And that will be the other main issue to be considered by network managers - are there currently applications in the market that actually has the capability to exploit the potentials of ATM in terms of providing end-to-end QoS solution to the fullest and to warrant the investment for providing ATM to the desktop?

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BIOGRAPHY

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TELECOMMUNICATIONS INFORMATION NETWORKING ARCHITECTURE (TINA) - AN OVERVIEW

Raja Mohd Rosli Raja Zulkifli

ABSTRACT

Telecommunications, information and entertainment industries are already converging at a rapid pace. The reality of today's telecommunications world is made of heterogeneous environments, with different transport and data networks, a variety of access means, an increasing number of terminal types, as well as an increasingly tighter coupling with computer and entertainment world. Quite frequently the different technologies do converge towards a homogeneous environment. This generates the need for interoperation at several levels, and also for common solutions across multiple domains and platforms as well as to share risks of development among multiple players participating in the same effort. To address these requirements, a new enabling framework called the Telecommunications Information and Networking Architecture (TINA) is needed. This paper hence, attempts to provide a brief overview on TINA and its technology foundation, the product of a global collaborative effort of the TINA-Consortium.

INTRODUCTION

The convergence of Telecommunications, Information and the Entertainment industries is already happening at a blistering pace. The ubiquity of multimedia products and devices along with other technologies for easier delivery of different types of content to the customer are testimony that this convergence is happening sooner than we had expected. In turn, this convergence will pose a whole new set of requirements for creating, managing and delivering of services over a multitude of platforms existing today and to share the risks of development among multiple players. To address these requirements, a more open and integrated framework or architecture namely the Telecommunications Information and Networking Architecture (TINA) specification is now being defined by the TINA-Consortium (TINA-C).

A BACKGROUND OF TINA-CONSORTIUM

Telecommunication Information Networking Architecture Consortium (TINA-C) was formed in 1993 on a global collaborative effort with more than 45 companies participating, consisting of major Telcos, equipment and software vendors whose main institution is the TINA-C Core Team, a pool of experts working together at the Core Team facilities in Bellcore, New Jersey (USA). The Core Team started its work in January 1993 and disbanded it in December 1997. Core Team members were sent by the Consortium member companies for a period of one to three years to contribute in the collaborative research work. Its main aim was to specify a common framework for the collaborative specification and deployment of services which are network and technology independent using the latest developments in software and object oriented technology to address the future convergence of telecommunications and the information market place. A complete listing of TINA-C membership as at the end of 1997 is shown in **Fig.1**.

TELECOM OPERATOR			
AT&T	Bellcore	BT	Cable & Wireless
CDOT	CSELT	Deutsche Telekom AG	EUROSCOM
ETRI	France Telecom	KDD	KPN
Korea Telecom	MCI	NTT	Portugal Telecom
Sprint	Stentor	Swiss PTT Telecom	Telecom Italia
Telekom Malaysia	Tele Denmark	Telefonica	Telenor
TELECOM MANUFACTURERS			
Alcatel	Ericsson	Fujitsu	GPT
Hitachi	Lucent Technology	NES	Nokia
Northern Telecom/BNR		OKI	Siemens
COMPUTER AND SOFTWARE COMPANIES			
DEC	HP	IBM	IONA technologies
Samsung	Softwire	Sun Microsystem	Unisys

Fig. 1: Members of TINA Consortium Phase 1

TINA-C has now entered its second phase (1998-2000) and being now renamed TINA Forum. It is designed to evaluate business cases while promoting a global scale proliferation of products and telecommunications component-ware industry.

TINA-C COLLABORATIVE EFFORTS-REUSE OF EXISTING RESULTS

TINA is the evolution outcome of Bellcore's Information Networking Architecture (INA), which is at the basis of TINA requirements, objectives and basic principles. Subsequently, in the life of

TINA-C, other results from different bodies have also been found to be crucial. Examples are CORBA architecture and model (IT world) and B-ISDN networks (Telecom World). They are now being produced, respectively, by Object Management Group (OMG) and by ITU-T. TINA-C specifications further incorporate existing standards and contribute towards other world standards bodies and industrial consortia among others ITU-T, NMF, ATM-F, OMG, DAVIC, IETF, etc. The extent of collaboration is depicted in **Fig. 2**.

TINA-C specifications produced by Core Team are validated by members' home companies involved in auxiliary projects. Other non-formal collaboration participating in the same effort includes the Universities and Research Bodies and as one example among many others, the ACTs Consortium.

TINA is intended to be the upshort of IN, meaning that it provides a better solution to fulfil similar requirements as IN (low time to market for services etc.) and adopts similar high level principles (e.g. separation between delivery functionalities and service provision).

After completion of the first phase of its existence (1993 to 1997), TINA Consortium has reached most of its objectives. Its coherent set of concepts described above is largely recognised in the industry as a reference for the evolution of today's architectures and the integration of telecommunications and information architectures.

REQUIREMENTS FOR TINA

From the outset, the huge requirements on convergence have posed a wide scope of deliverables that TINA architecture should support, such as:

- A wide range of services(Communication, Information and Management services)
- Rapid Service deployment and Provisioning (to reduce development and deployment costs by component reuse).
- Support for multi-player environment (to open the environment for interoperability among multiple providers/ operators).
- Universal Service Access (access to services independent of physical location and terminal used).
- Independence from Network Infrastructure (for services to evolve independently of the underlying transport and computing technologies).
- Service Manageability (for integration of control and management by adopting a common approach for service management).

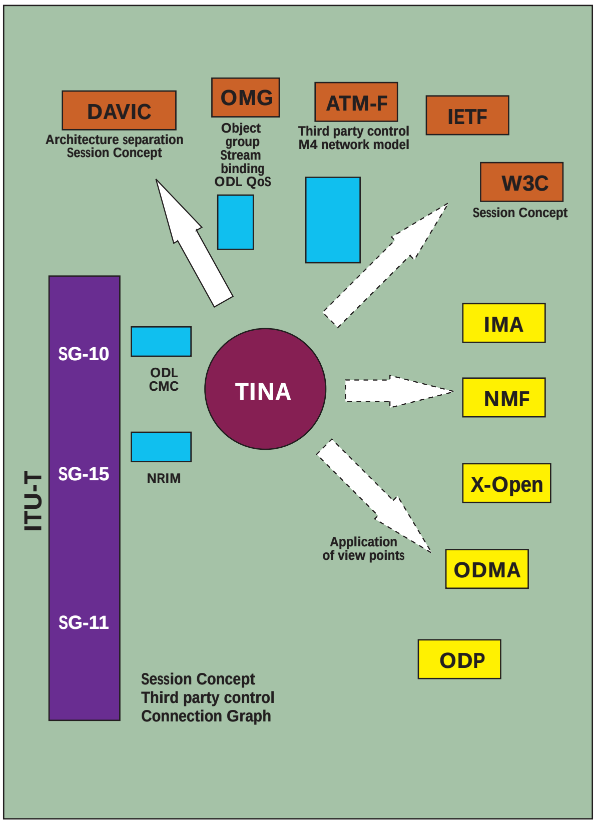

Fig. 2: TINA-C Standards Collaboration

It is important to bear in mind that such a complete framework to address the requirements above has not been defined elsewhere and has only been defined by TINA-C.

TINA ARCHITECTURE AND FOUNDATION

Telecommunications Information Networking Architecture was to define a common software architecture that resolves the increasing complexity of creating and managing new services, be they mobile, fixed or multimedia services. TINA is intended to be applied to all parts of telecommunications and information systems for example, terminals (personal computers, etc.), transport servers (switching systems, routers, etc.), service servers (VoD, web, etc) and management for TINA products.[1]

The architecture is based on four principles namely:

1) Object-oriented analysis
2) Distribution
3) De-coupling of software components, and
4) Separation of concern.

Object oriented analysis captures the complexity of a system from different angles and breaks it down into a set of models.

Distribution of service software components over different parts of the network accommodates traffic characteristics, network load or survivability and specific customer demand. The distribution is supported by the Distributed Processing Environment (DPE).

Software components are *de-coupled* from each other so that a change in one component due to a change in underlying technology (standards, languages, programs, materials, networks, etc.) would not affect other components.

TINA provides for two major *separation of concerns.*

i) The first separation is between the applications and the environment (ie. DPE) on which they run.
ii) The second is separation of applications into the service specific part and the generic management and control part. The latter interacts with transport and other elements.

TINA is a layered architecture as shown in **Fig. 3**. The DPE (Distributed Processing environment) hides the underlying physical infrastructure when applications are deployed and communicate among each other. However, a part of TINA mission is to provide a way to control and manage network elements. To solve this problem, an approach similar to the Telecommunications Management Network (TMN) has been adopted; the fundamental enhancement with respect to TMN is the introduction of the DPE. The network elements provide a standard agent/manager type interface based on an object oriented Network Resource Information Model (NRIM), which is an abstract view of network resources. The interaction between the agent and the actual resources is proprietary. On top of it, several management layers (which in TINA, are also used for real time control purposes) interact with the DPE.

As shown in the figure the main separation principle is between different parts of the architecture.

TINA is composed by:

- A Service Architecture, defining a set of components that provides a set of common capabilities to support a variety of services. These capabilities include aspects like call control, access to services, personal mobility management.

- A Resource Architecture, defining a set of components that provides capabilities to control and manage network resources. These capabilities include aspects such as connection control and FCAPS (Fault, Configuration, Accounting, Performance, and Security Management).

- A Computing Architecture, defining a set of components supporting distributed processing. The core of the Computing architecture is the TINA DPE. The Computing Architecture also provides a general model to be used by Service and Resource Architecture of software applications.

Tina Components

TINA applications are modelled as components

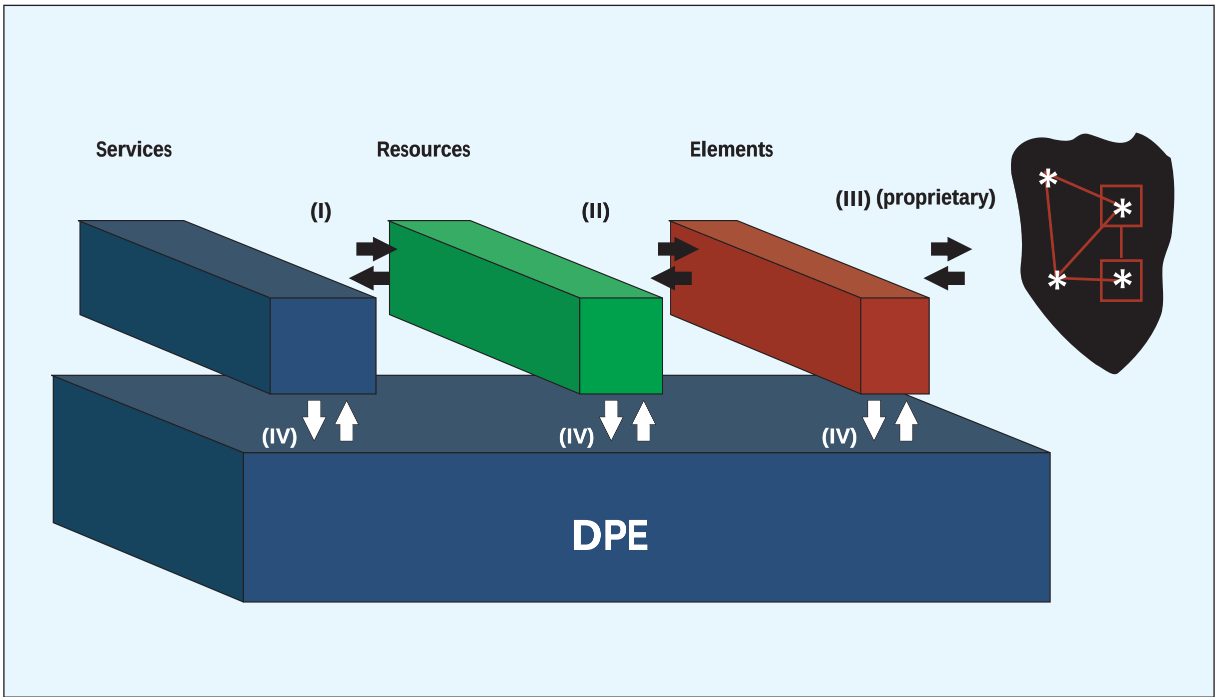

Fig. 3: TINA architecture separation

(which will soon appear as objects or group of objects) running on top of a distributed processing platform (DPE) as in **Fig.4**. DPE provides location transparency to the objects: applications can interact independently of their physical location where they reside and of their being distributed across a network. However, below DPE level those transparencies do not exist. DPE has to reside in all nodes (switching systems, OSSs, control nodes, etc) of the network. Pieces of DPE scattered around the network interact via Kernel Transport Network (kTN), a sort of signalling network with high reliability requirements.

Nodes are composed of some hardware and Native Computing and Communications Environment (NCCE). NCCE is a way of considering all software components in a processing node that is not specific for TINA, but of which TINA software has to be aware of (an example of a part of NCCE is an operation system). Nodes are inter-connected by a physical transport network.

The purpose of these principles is to ensure *interoperability, portability and reusability* of software components and *independence from specific technologies*, as well as to *share the burden of creating and managing a complex system* among different business stakeholders, such as consumers, service providers, and connectivity providers.

The TINA Business Model

Having to support an open multi-provider and multi-vendor environment in the multimedia age, TINA has to take into account different business roles. TINA Business Model provides a framework for interaction between different business major roles. This model sets constraints on the Inter-domain reference points which are defined between domains as in **Fig. 5**. The concept of Role (a position in Telecom market) and Stakeholder (a business entity ie. a company) described above determines a business model. The entities are roles while stakeholders can -hold one or more roles. A domain is the scope of one role. Entities (Roles) involved are:

- end users,
- retailer (provider that has a direct contractual relationship with end-users to provide a service)
- broker (the middleman putting end users in direct contact with retailers)
- Service Provider (a provider that has no privity or direct contractual relationship with end users) and
- Network Provider (a provider that owns a transport network)

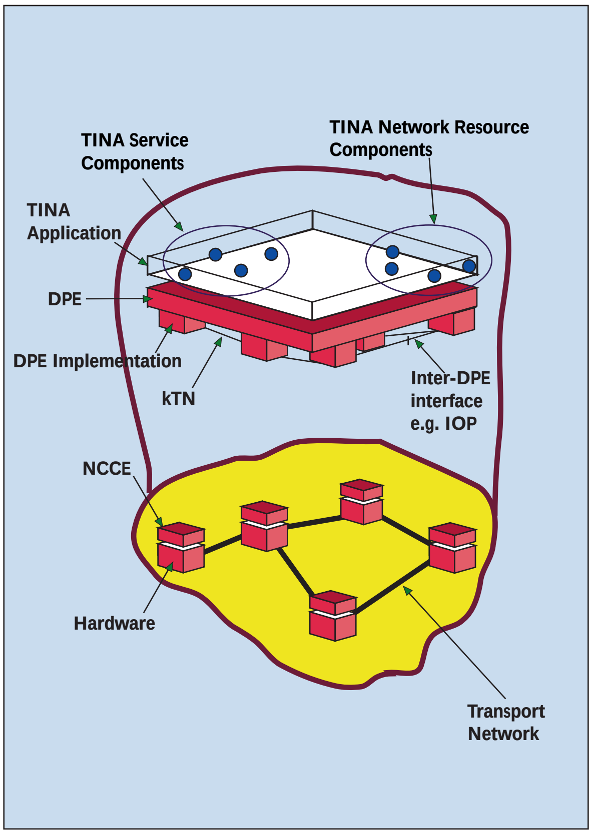

Fig. 4: TINA Components based on DPE

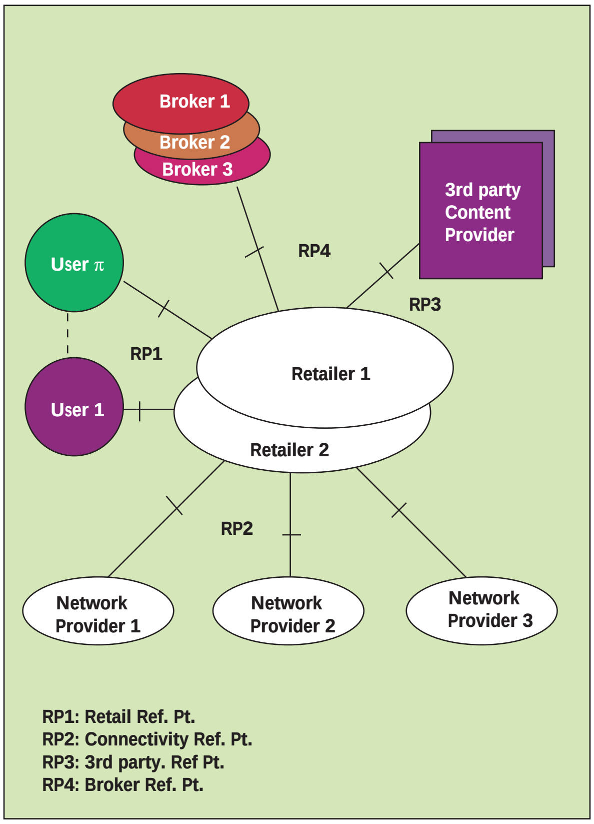

Fig. 5: TINA enterprise model

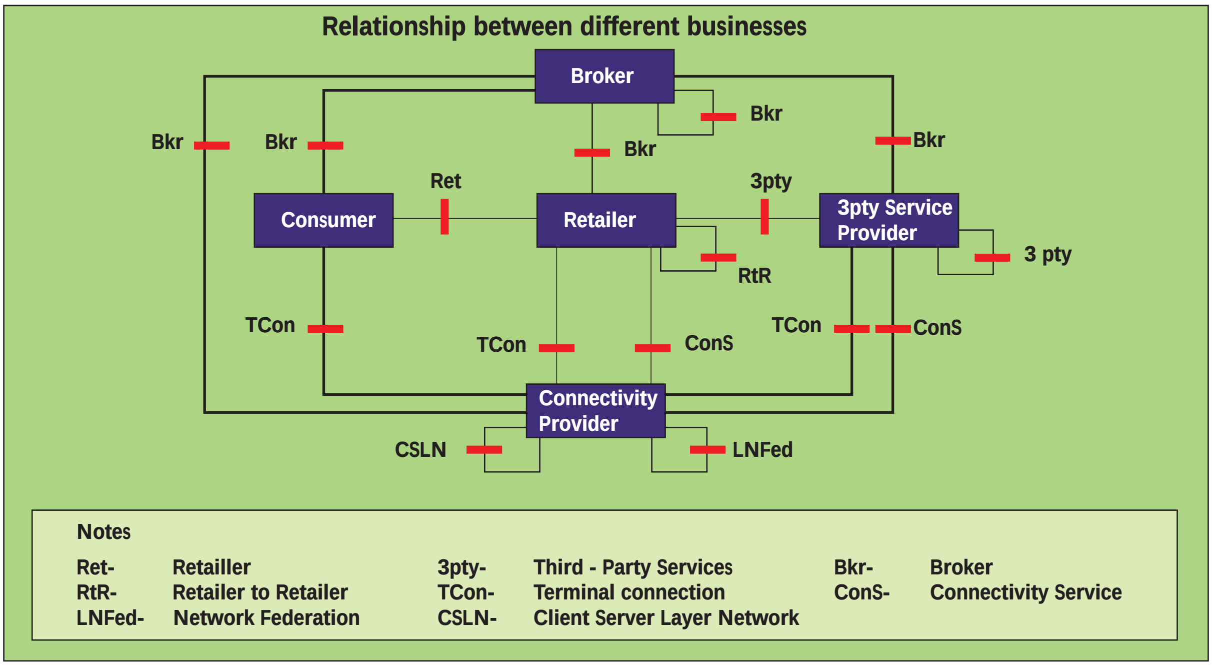

Fig. 6: TINA Business Model and Inter-domain RP

Fig. 6 shows the framework or the interaction between business roles that TINA architecture facilitates. The specification of a set of interfaces are defined as conformance requirements that apply to components within a domain. These interfaces are specified in TINA to help a stakeholder to compose a system of multi-vendor components. A vendor will build TINA components by conforming to Intra-Domain and Inter-Domain Reference Points.

These Reference Points (RP) allow a stakeholder to play multiple roles and still comply to a common framework for interoperability. The interfaces or reference points are namely:

- **Ret RP** (Consumer-to-Retailer) business relationship: providing the access and management to end-user services, and providing life-cycle management of users.
- **Cons RP** (Connectivity service) business relationship: providing control and management to connectivity.
- **RtR RP** (Retailer to Retailer): Retailer-to-Retailer business relationship providing access and management to services.
- **Broker RP** Broker business relationship: providing exchange and management of the broker information.
- **Tcon RP** (Terminal connection) business relationship: providing access management between connectivity provider and connectivity user.
- **3rd Party RP** (Third party) business relationship providing access and management to content and service logic.
- **LNFed RP** (Layer network federation) business relationship : providing peer control and management between connectivity providers
- **CSLN RP** (Client-server layer network) business relationship: providing control and management of server layer network.

Conformance to TINA at TINA Reference Points must guarantee both co-operative service provision among multiple stakeholders and interoperability of multi-vendor equipment.

TINA SERVICE ARCHITECTURE AS A MULTI-NETWORK INTEGRATOR

The reality of today's telecommunications world is made of heterogeneous environments, with different transport and data networks, a variety of access means, an increasing number of terminal types, as well as a tighter and tighter coupling with the computer world. Not necessarily the different technologies do converge towards a homogeneous environment. This generates the need for interoperation at several levels, and also for common solutions across multiple platforms.

At network level, each transport system is "autonomous", in that it guarantees a specific access or delivery service: cellular phone systems grant mobile telephony, IP and Internet the transport of information packets with "best effort" characteristics, and so on. The problem is that in most cases each network comes bundled with its own specific services on top: voice mailbox services offered by cellular operators for their users are completely separated from voice mailboxes on the Internet, even if the service is the same.

TINA Service Architecture represents a tool for a unified (overlaid) service layer for existing networks.

Fig. 7 illustrates this situation. TINA Service Architecture is a common platform for providing advanced services to a variety of interacting telecommunications networks.[2] Users access service platform via a variety of networks; each can be targeted to a specific class of customers, and each single customer can also access the service platform from different networks. They all share a common service platform and, in many cases, common services. This imposes to the service platform to support a variety of protocols and interfaces in order to interact with several network infrastructures. In this sense the service platform structured à la TINA has to *adapt* to the control and management interfaces of the underlying networks.

OVERALL PERSPECTIVE ON THE APPLICABILITY OF TINA

TINA is not meant to be as a total alternative or replacement to other architectures because TINA overlaps, but does not cover exhaustively other architectures. Instead, TINA has to be viewed and consequently developed as a framework that can be superimposed on all other architectures (Intelligent Network, TMN, Internet, B-ISDN), whenever it brings benefits.[3]

What is necessary in order to add value to existing or future systems with the introduction of TINA is a *library of components*, defined according to the TINA principles. They can be introduced to "fill holes" in IN, TMN, Internet, B-ISDN.

These components must have a high degree of reusability (which means that they have to be "small") and must be able to seamlessly fit into a variety of legacy systems, interacting with existing protocol stacks by means of APIs, possibly corresponding to adaptation units. In this way TINA becomes a means

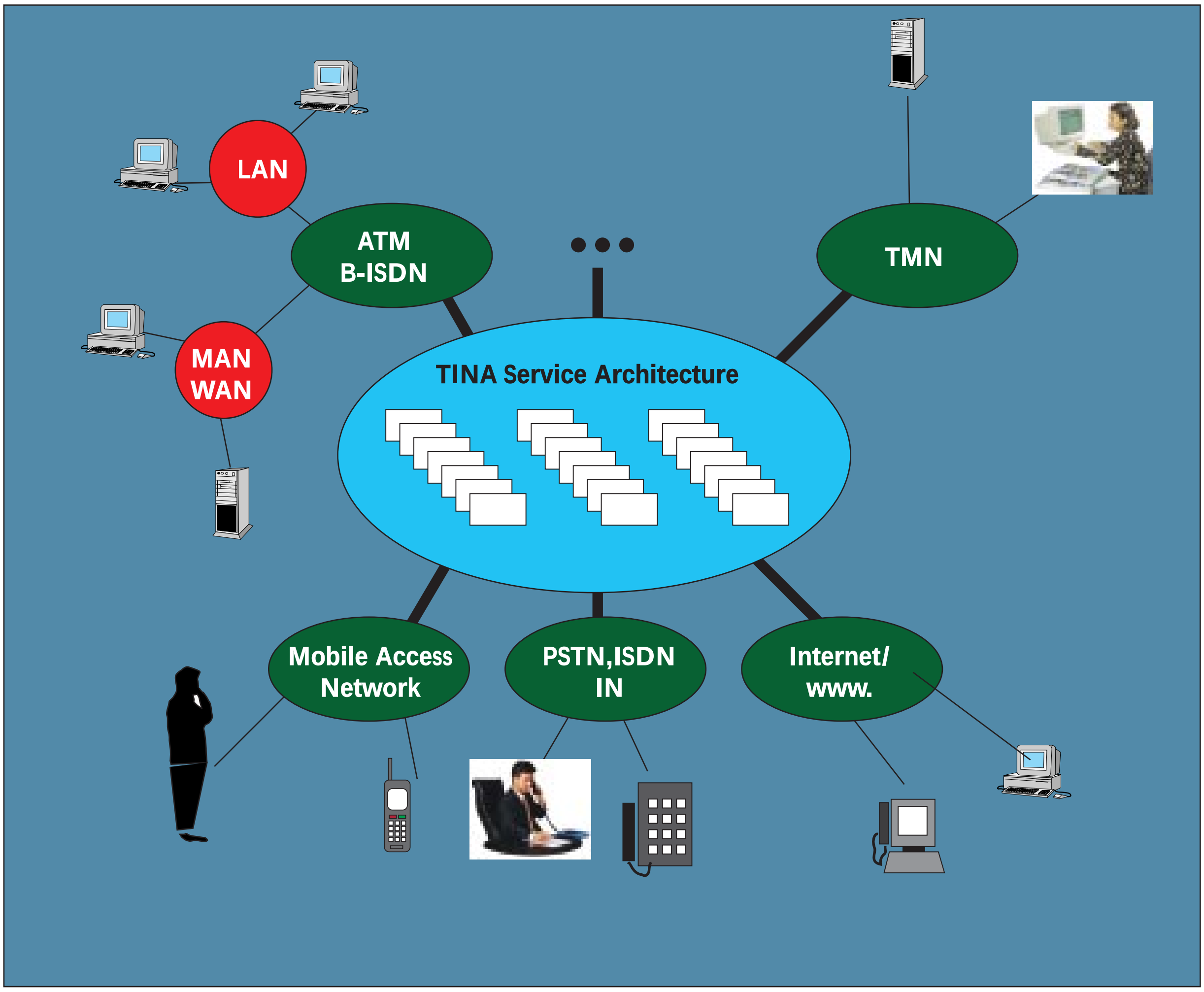

Fig. 7: TINA Service Architecture as a common service layer for multiple networks

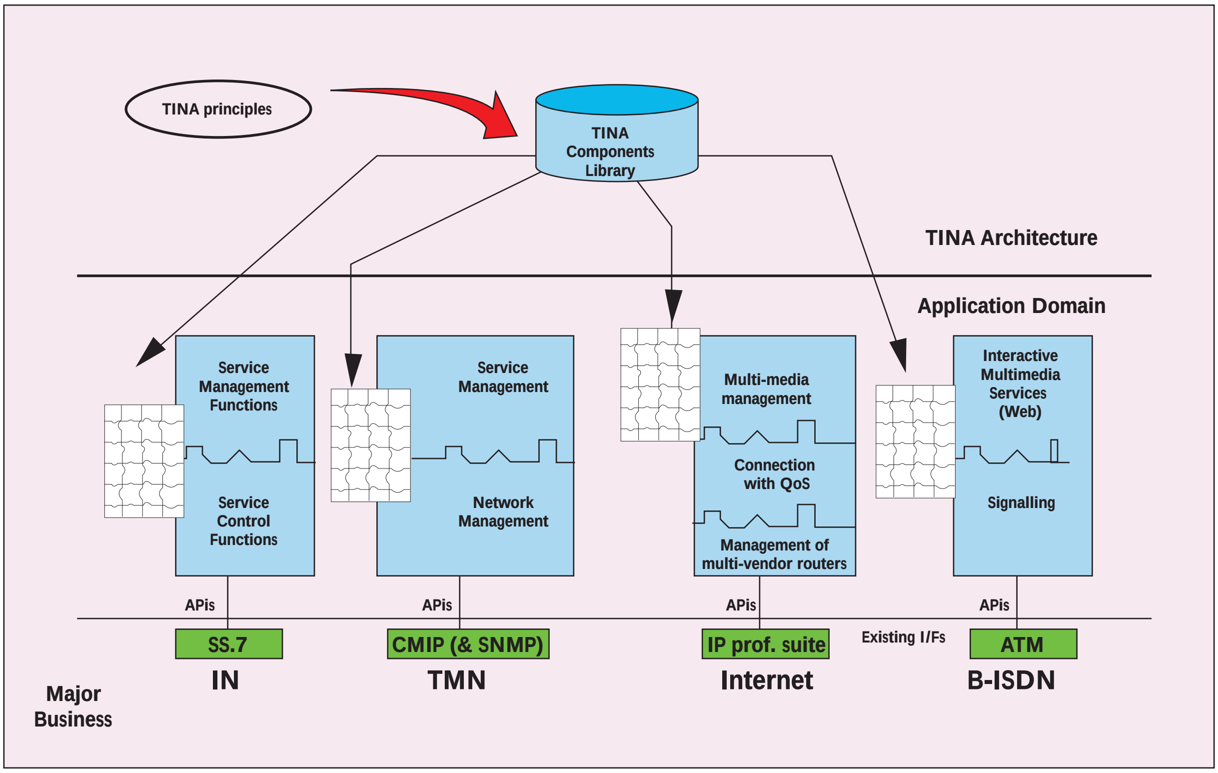

Fig. 8: Reusable components over different networks

to integrate different architectures in a common framework providing interoperability, flexibility and programmability. In addition, the specification and availability of small components can foster the market of components. In this way TINA could be seen as a component-ware for telecommunications industry as in **Fig. 8**.

CONCLUSION

TINA Architecture using object oriented software and distributed processing as a new paradigm to address the complexity and convergence of the future telecommunications and IT systems is gradually approaching maturity. Rigorous testing of TINA components and specifications in the industry during TINA Forum Phase2 (1998 –2000) will result in the proliferation of available component-ware and APIs in the market place within an expected time frame of three to five years. This will be as an enabler towards faster convergence and integration of the three major industries resulting in open interoperability between multiple providers in the market place besides shielding future system and application designers from the complexity of future systems.

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BIOGRAPHY

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MICROSTRIP ANTENNA BANDWIDTH ENHANCEMENT TECHNIQUES

Sharlene Thiagarajah

ABSTRACT

The most serious limiting factor of a microstrip antenna is its narrow bandwidth, in the order of 1% - 2%. Various approaches have been proposed to overcome this problem but an 'ideal' solution is yet to be found. This paper provides a survey on the different approaches used to increase the bandwidth of a microstrip patch antenna. They include, using substrates with low unloaded-Q wideband impedance-matching networks, arranging elements into an array and utilizing the double resonance phenomenon. Each method proposed here has its own viability and limitation. Perhaps a combination of the various approaches presented in this paper could lead to an optimum wideband antenna configuration.

INTRODUCTION

An antenna system is fundamental in completing the structure of a wireless network. It acts as the first and last stage for signal reception and transmission, but its importance is commonly overlooked. Selection of a proper antenna system can significantly reduce signal processing requirements, power consumption, improve coverage and quality of service.

Research engineers are constantly looking for new antenna elements that can provide optimum performance requirements for wireless applications. In R&D Division of Telekom Malaysia, the microstrip antenna (MSA) is investigated for its physical and electrical attributes. Due to high bandwidth requirement for cellular communications, the application of an MSA proved to be impractical, hence bringing about investigations on numerous bandwidth enhancing measures. This paper provides a comprehensive survey on the various bandwidth enhancing method employed, its practical implementation and results.

MICROSTRIP ANTENNAS

Linearly polarized microstrip antennas operate at resonance and their operating bandwidth is generally limited by its input impedance variation at the feed point. A commonly used definition for bandwidth is the frequency range over which the input VSWR < 2, and percentage bandwidth is found to be linearly proportional to antenna frequency.

For simple rectangular or circular structures, bandwidth can be increased proportionately either by increasing the substrate height and/or by reducing the dielectric constant.[1] In both cases, the Q-factor will decrease. However, there are practical limitations to decreasing the dielectric constant and furthermore, the increase in substrate thickness is limited by:[2]

- Excitation of surface waves that will reduce radiation efficiency as well as that will cause undesirable effects on the radiation pattern.
- Problems will occur in feeding the patch as the substrate thickness increases.
- Higher-order cavity modes with fields depending on substrate height may develop, introducing further distortion in the radiation pattern and impedance characteristics.

Therefore a more efficient method has to be found that enables bandwidth to be increased without adversely affecting the other electrical characteristics of the patch antenna.

BANDWIDTH ENHANCEMENT TECHNIQUES

There are various bandwidth enhancement techniques proposed thus far, and can be categorized into the following approaches :

- Substrates with Low Unloaded Q.
- Employing Wideband Impedance-Matching Networks.
- Contriving an Arrangement of Elements into an Array Antenna.
- Utilizing Double-Resonant Phenomenon.

Using Substrates With Low Unloaded Q

The radiation efficiency of a patch antenna is inversely proportional to its Quality Factor (Unloaded -Q) which in turn is achieved by increasing substrate height. The problems associated with this method have been clearly mentioned earlier, but a solution has since been found.

An experiment conducted using a paper honeycomb material as a substrate has shown a wideband performance of 8.75%.[3] This type of substrate was able to reduce the unloaded Q of a circular patch antenna, to achieve a low dielectric constant of (r = 1.21, with a total thickness of 12.3 mm. Here material selection plays an important role in providing the necessary unloaded Q required for bandwidth enhancement of a patch antenna.

Wideband Impedance-Matching Networks

This method is devised based on the fact that for usual microstrip patches, bandwidth is limited by its reflection loss at the feed and not by its radiation characteristics.[4] A wideband patch antenna can be realized if impedance matching can be achieved over a wide frequency range.

Reactive Networks

The objective of impedance matching is to match as best as possible a frequency dependent load impedance to a source (or feeder) over a prescribed frequency range. This can be achieved by designing a reactive matching network. The network can either be coplanar with the antenna or placed at the back of the groundplane so as not to disturb the radiation pattern as shown in **Fig. 1** below. This method can increase the bandwidth by about 4 times, in the S-band.

Dual Feed Structure

Another method to ensure image impedance remains near constant over a wide band of frequencies, is to simultaneously excite two modes using two feed structures. This can be achieved by adjusting the coupling so that the two modes present complementary impedances, one in series and the other in shunt, at the same point on the feeder. Experimental results indicate that the radiation pattern is stable over a wide frequency band and hence, the operating bandwidth will likely be determined by efficiency or power gain rather than by impedance or radiation pattern.[6]

The use of modes with complementary impedance behaviour not only provides a wide impedance bandwidth, but also results in an antenna which is directional, even though small. In fact, this feature could be exploited in direction finding and homing

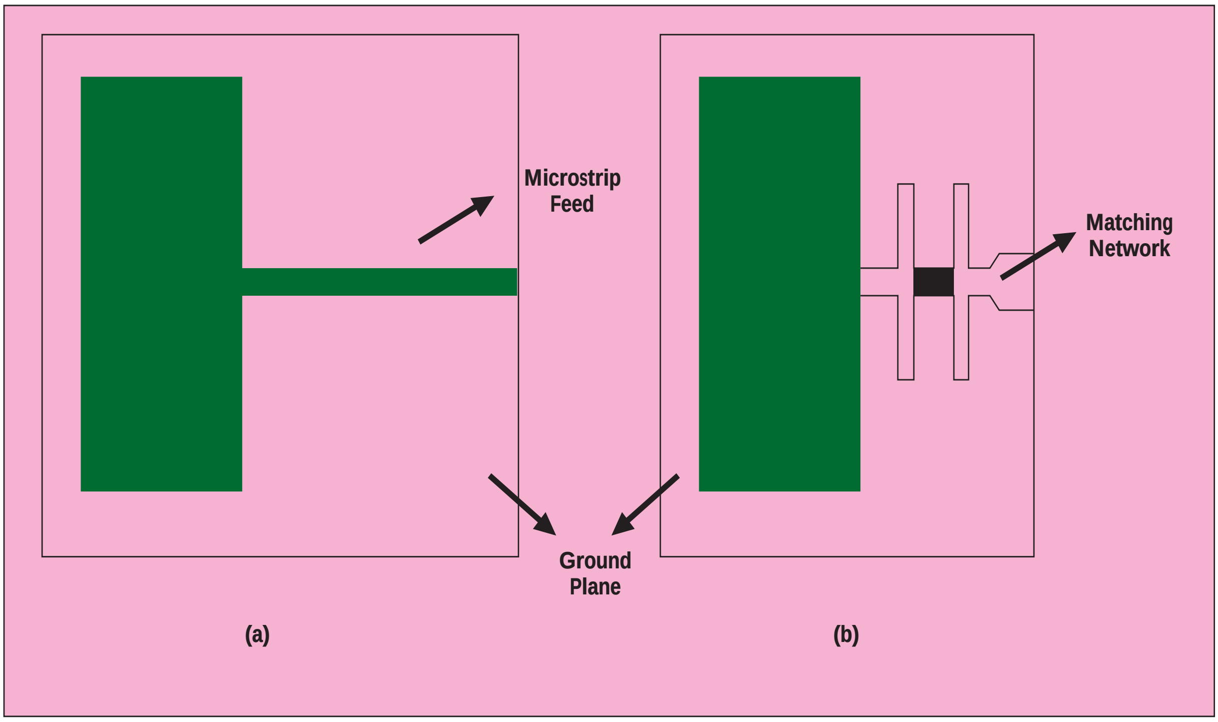

Fig. 1: (a) Plane View of Standard Rectangular Patch Antenna Excited by Microstrip Line

Impedance matching becomes necessary to elevate the problem that arises when feeding thick substrates. When a thick antenna element is fed by a coaxial probe, this probe will introduce a series reactance almost proportional to substrate thickness,[5] hence proper matching will become exceedingly difficult. Although in principle the mismatch can be improved by repositioning the probe location, but this will cause the resultant bandwidth to be less than ideal. Hence a reactive network (i.e. a series resonant LC circuit) can be considered as the first stage of a broadband matching network.

systems. The antenna also responds to both electrical and magnetic fields, a property that can be quite useful in diversity receiving systems.

Arrangement Of Elements Into An Array

The key concept of this method is that stagger-tuned resonators lead to wider bandwidth. Bandwidth improvements of the order of seven times the bandwidth of a single patch have been realized by multiple resonator configurations.

Multiple Gap-Coupled Resonators

Two associated problems arise, large area requirement and deterioration of the radiation pattern over bandwidth.[7] Both these problems can be overcome by using multiple resonators gap coupled along the non-radiating edges.[8,9,10] **Fig. 2** shows two configurations, the non-radiating edges gap-coupled microstrip antenna (NEGCOMA) and four edges gap-coupled microstrip antenna (FEGCOMA).

In NEGCOMA, two additional resonators are placed adjacent to the non-radiating edges of the rectangular patch antenna as shown in **Fig.2(a)**, and in FEGCOMA, four additional resonators are gap-coupled to all four edges of the rectangular patch antenna as shown in **Fig.2(b)**. The FEGCOMA configuration consists of multiple resonators of slightly different resonant lengths, which gives staggered resonant frequencies, hence providing broader bandwidth.

The experimental results are in reasonable agreement with theoretical analysis, where bandwidth of 480 MHz and 815 MHz were obtained for the three resonator and five resonator configurations respectively in the S-band. Unfortunately, these coplanar parasitic resonators are cumbersome and their association into arrays usually introduce grating lobes. Moreover, although the coupling effects between the active and the parasitic elements are taken into account in each unit cell, the strong coupling between all the cells are often neglected. To conciliate all the advantages, monolayer arrays made up of two strongly coupled interdigitated periodic subarrays of either square or triangular elements were investigated.[11] Frequency bandwidth obtained with this geometry is larger than conventional monolayer microstrip antennas.

Parasitic Coupled

Parasitic coupled only to the non-radiating edges of a rectangular microstrip patch antenna can also improve the impedance characteristics of an MSA. Radiating edge (width) of the driven patch is reduced, while parasitics of various widths but of the same length, are coupled to the non-radiating edges of the patch.

This method enhances the bandwidth while not causing deterioration of the radiation pattern or an increase in the overall size of the antenna, but due to the shorter lengths of the radiating edges, efficiency may be less. With this method, the parasitic and the driven element will resonate at adjacent frequencies thus giving a flat impedance characteristics over a wide band of frequencies. Experimental results produced a bandwidth of 6% (VSWR < 2.0), a

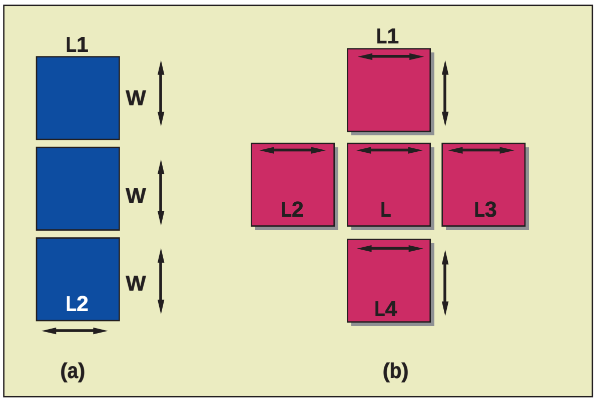

Fig. 2: (a) NEGCOMA (b) FEGCOMA

bandwidth 8 times that of a corresponding planar antenna.[10]

Circularly Polarized Arrays

With circularly polarized array antennas, bandwidth can be increased by using a sequential rotation arrangement technique, where each radiator is a single-fed circular polarized element with small notches. Experimental results show that the sequential array antenna has a much wider bandwidth than the conventional design.[3] **Fig. 3** below shows an array configuration, where each circular patch is fed individually via coax.

Double-Resonant Phenomenon

This method increases bandwidth by exciting two resonant frequencies close together, making its combined bandwidth considerable. This double resonant phenomenon can be achieved by using

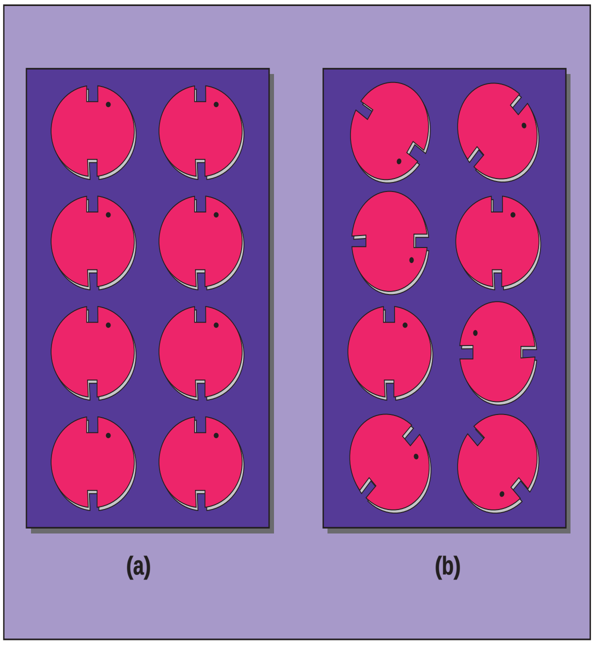

Fig. 3: 4 x 2 Array Configuration (a) Conventional Arrangement (b) Sequential Arrangement

shorting pins, vertically stacking patches, co-planar feed lines, air gaps or by electromagnetic coupling.

Shorting Pins

For a single element antenna to operate at dual frequency, the radiation pattern polarization and impedance must be similar in all frequency bands. Zhong and Lo,[12] experimentally demonstrated the effects of shorting pins on the frequency and impedance, where the number of pins placed and its position will determine the two resonant frequencies of the patch. Bandwidth with reference to 3 : 1 VSWR is about 2% for the low band and almost 8% for the high band.

Vertically Stacked Patches

This method involves multiple patches stacked vertically. The usual arrangement is where the top patch (called director) is slightly smaller than the lower one, like the Piggyback antenna developed by Schaubert and Farrar[1] as shown in **Fig. 4** below.

A slightly different configuration where the top patch (parasitic) is larger than the lower patch have also been used. In this case, the lower patch acts as the feeder and provides impedance match over a wide frequency range.[3] Theoretical investigations found that input impedance varies significantly with the size and position of the parasitic patch.[13] An experiment conducted for a circular patch antenna with a parasitic element, produced a wideband performance of 8.5% for a VSWR < 1.5.[3] Hence the effect of the parasitic element on antenna bandwidth was confirmed to be considerable.

Electromagnetic Coupled

The electromagnetic-coupled patch antenna (EMCP) is another method used to enhance the bandwidth of a patch antenna. The basic geometry of the EMCP is shown in **Fig. 5**. Each conducting patch is fabricated on an electrically thin substrate and separated by a region of air or foam with $\varepsilon r \approx 1$. The top and bottom patches are referred to as the radiating and the feeding patches, respectively.

Studies on EMCP rectangular patch antenna,[2] shows that characteristics of the antenna can be separated into three regions depending on the width of the air-gap Δ, for Δ (between 0 and 0.37λo. Region 1 is associated with bandwidths

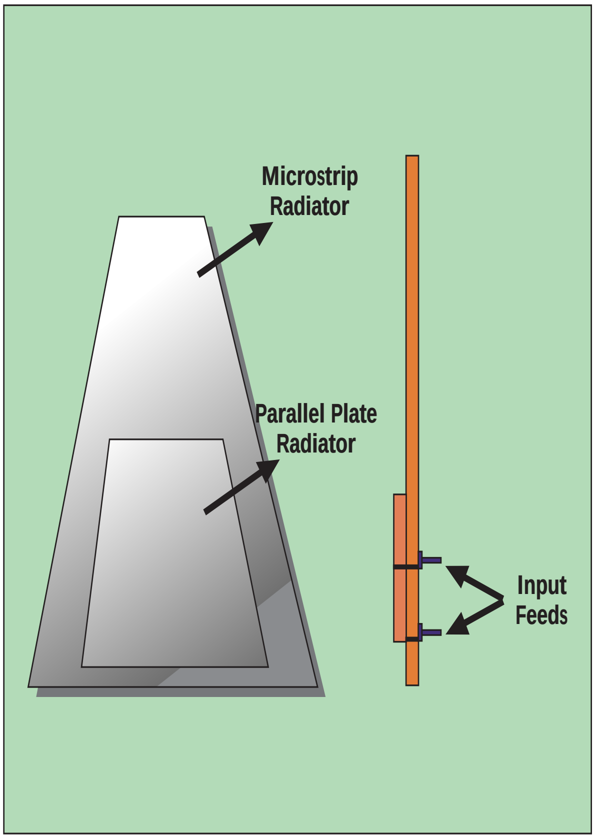

Fig. 4: Piggyback Patch Antenna for Dual Frequency Operations

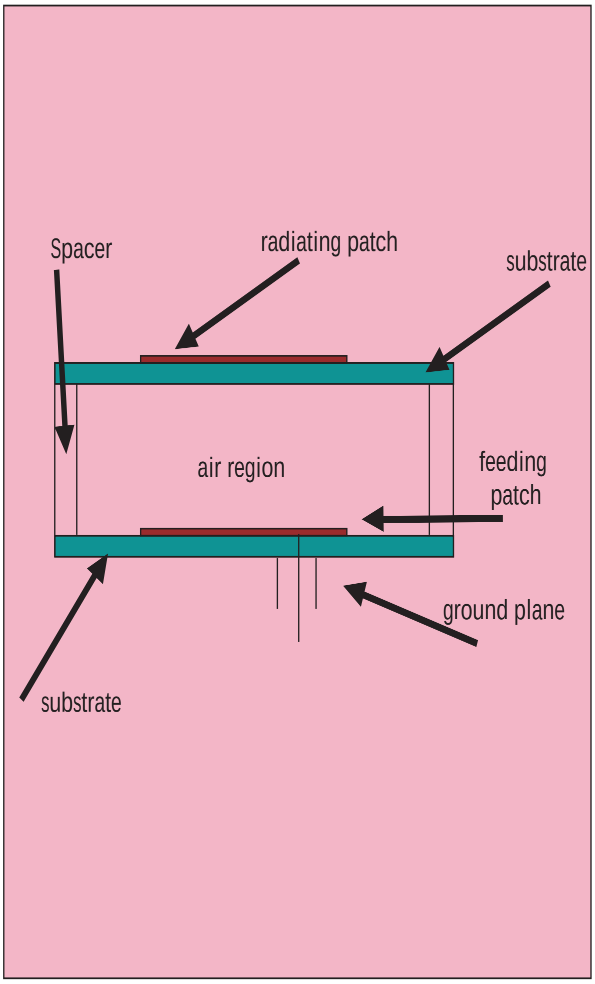

Fig. 5: Electromagnetic-Coupled Patch Antenna

exceeding 10%, region 2 has abnormal radiation characteristics while region 3 is associated with narrow beamwidth and high gain. When operating in Region 1, the EMCP offers promising bandwidth in excess of 10%. Using this same concept, a triple patch microstrip antenna was proposed using three layer circular EMCP elements consisting of a feeder patch at the bottom and two parasitic patches on the top, stacked vertically with air regions in between.[14] All the three patches are of identical radius to operate in S-band frequencies. Experimental results indicate an impedance bandwidth as high as 20%, high gain and good radiation characteristics. Scan performance of the array was reported over a scan sector of $\pm 40^{o}$ and hence is quite encouraging for compact low cost planar array solutions.

Co-planar Line Feed

Feeding these multilayer patches, either by coaxial probe or slot coupling can also affect the increase in bandwidth of a patch antenna. Generally, slot-coupled structures should be used at frequencies higher than the C band, if radiation specifications are severe. Probe-fed structures are better suited to lower frequencies and to applications in which electromagnetic compatibility is a major constraint, since back-scattering radiation from a slot is significant.[7]

A new proposed feeding method based on a simple monolayer microstrip patch simply fed by a coplanar line can achieve bandwidth up to 5% in the S-band and 10% in the C-band with a 0.09"-thick substrate.[15] The proposed concept eliminates the need for multilayer techniques and so permits the antenna application in structurally and thermally severe environments (i.e. aerodynamic constraints and thermal flight conditions). This idea is applicable to any shape and its main advantage lies in its single layer structure which allows coplanar etching.

CONCLUSION

Microstrip antenna is one of the most innovative topics in antenna technology today. This trend is likely to continue due to mechanical and fabrication features of the microstrip antenna, which makes them very appealing from a systems perspective. The possible wide spread application of this antenna is limited by MSA's electrical characteristics of narrow bandwidth, low gain and lower power handling capabilities. Nevertheless, MSA's physical attributes of low-cost,[3] lightweight, conformability and easy integration with solid-state devices and MMIC's that have sustained its appeal and led to many research topics on improving its electrical limitations.[16]

For Telekom Malaysia, the application of conformal antennas is very attractive especially for mobile communications in the indoor environment at 1.8GHz (PCN), or on subscriber terminals for Wireless Local Loop (WLL) applications. These antennas also find their applications for higher frequencies (Wireless) LAN and Wireless ATM applications where its small size and flush mount capabilities makes them easy to hide. Narrow bandwidth available from these low profile radiators is recognized as the most significant factor limiting the application of this class of antenna. Different approaches have been proposed but the search for an 'ideal' wideband printed microstrip antenna is still on.

Substrates with low unloaded-Q introduce surface waves, higher order modes and feeding problems that cause mismatch at the feed, while impedance matching techniques are generally avoided as they make networks more complex and dissipative. Dual frequency technique using two separate frequency bands, assigned to each patch antenna, increases bandwidth without the need for an external duplexer. Generally, (certain) vertically stacked patches and array antennas are more popular as it reduces overall size while not compromising on its radiation characteristics or conformal nature.

Material development is another area that offers the possibility of improving microstrip antenna characteristics.[17] A likely possibility is the use of ferrite materials that could improve the frequency and polarization agility or beam steering of an MSA.

Alternative novel feeding methods should also be studied and used in combination with present bandwidth extension techniques. For example using parasitics, gap-coupled to the non-radiating edges of a driven patch fed by a coplanar line instead of a coaxial probe as precise matching (at the feed) for a wide range of frequencies could further increase the bandwidth of a microstrip patch antenna.

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BIOGRAPHY

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APPLICATION OF SIMULATION IN TELECOMMUNICATIONS NETWORKS

Zailani Omar and Mohd. Noah Mohd. Salleh

ABSTRACT

This paper presents the significance of using simulation technique in telecommunications networks. The use of simulation is to help the managerial level especially for their network design community to plan on network performance. The paper will introduce a simulation methodology and the reasons why the perspective should be used in the operation of telecommunications industry fittingly especially in network division. From the experience of using simulation as a tool to predict performance of the network, there are some guidelines and lessons on how to use simulation properly.

INTRODUCTION

Normally simulation assist people in the network design community in performance planning. It is a tool that gives the user an interactive modeling environment with a graphical user interface. It is also defined as a tool that allows the definition of a network topology, the nodes and the links that go towards making up a network. A general model of network simulation is developed without restricting their possible ranges and without oversimplifying the model beyond a reasonable level. In developing the model, we are actually studying and evaluating the performance of networks. The task of modeling is simply that of representing the entire system in terms of a network of nodes belonging to certain levels of a hierarchy.

PURPOSE

Actually a simulator is a tool to analyze the behavior of networks without the expense of building a real network.[1] There are two major uses for the simulator.[2] First, simulator as a tool for network planning and second, simulator as a tool for system/protocol performance analysis.

As a planning tool, a network planner can run the simulator with various network configurations and traffic loads, to obtain statistics, (such as utilization of network links and throughput rates of virtual circuits). So it can be used to answer questions such as:-

i. Where will bottlenecks be in the planned network
ii. What is the effect of changing the speed of a link
iii. Will adding a new application cause congestion

As a system/protocol analysis tool, a protocol designer could study the total system effect of a particular protocol. For example in an ATM network, activities can be recorded on a cell by cell basis for analysis.

NETWORK PERFORMANCE PREDICTION

Network simulation is one technique we can use to predict the performance of a network. **Fig.1** shows the division of network simulation in telecommunications.

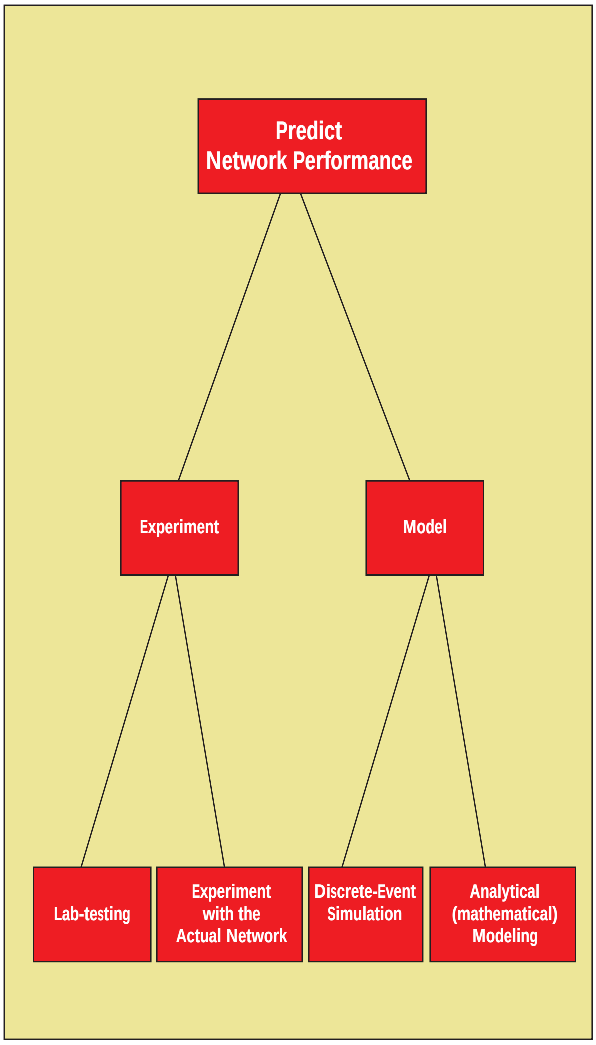

Fig.1: Division of Network Performance Prediction

Experimenting with actual equipment approach is useful when investigating new network technologies or applications on a small scale. The downside is that it is very costly in terms of time and equipment. To make changes to the production network is a very risky approach due to its potential to bring down the network and costing an organization millions of ringgit in lost productivity. Lab testing is valuable for collecting detailed data that will be used in simulation.

Analytical modeling involves creating a number of equations that describe network's performance and solving them for the unknown such as utilization and latency. The benefit of this approach is that, computationally, it is very fast to solve even a large model issue. The downside is that analytical modeling is not able to account for all the complex behaviors that applications and network devices exhibit. Accurately predicting latencies is limited due to simplifying assumptions that are often made to make mathematical analysis tractable.

Discrete-event simulation uses a model where traffic is represented as sequences of messages, packets or frames. Movement of traffic is simulated by keeping track of state of the network devices and traffic sources as they evolve over time. An important aspect of discrete-event simulation is the abstraction that is used both in the device and traffic modeling.[3] Every simulation model has a range of operation under which it is valid. A broader range generally requires a more complex model, resulting in more time to construct and execute the model. Therefore, it is important to focus on a certain subset of problems.

SIMULATION METHODOLOGY

In order to effectively use simulation, a methodology should be used that includes collecting the data needed for simulation. Knowing both topology and baseline traffic of network are essential information prior to building a simulation model. Secondly, if we are planning to assess the impact of a new application on the network, we must have an understanding of the type of traffic the new application will put on the network. Identify the traffic generated by a particular application. Once we have established the application profile, we can create new nodes or add new the applications to existing nodes. First, determine the overall loading impacts of the application. Determine if the existing network has sufficient capacity for the application. Create capacity and other adjustments to the network to get the segment and link utilization within design goals. Next is to determine how transport protocols and protocol overheads affect the results.

CONCEPTS OF SYSTEM ANALYSIS AND DESIGN

Fig. 2 illustrates the life cycle of a properly designed network system. Ten tasks are executed in sequence of one series. The most important task is the ongoing tabulation by a system engineer of all analysis data along with their design tools collected from current network systems and those collected from other previous network systems.

There are three basic methods of analyzing system performance.

1. Physical S simulation, which requires the availability of the final system under investigation. Tests are performed under typical traffic loads to obtain all aspects of the performance. This is by far the most expensive and time-consuming approach.

2. Computer simulation which requires a software modeling of all operations and running the program until one achieves a statistical equilibrium. Development of the simulation software may take a sizable amount of time.

3. Analytic simulation, which employs well-proven analytical techniques for modeling and predicting the performance of a network system or its elements. This is by far the most elegant, quickest and cheapest method.

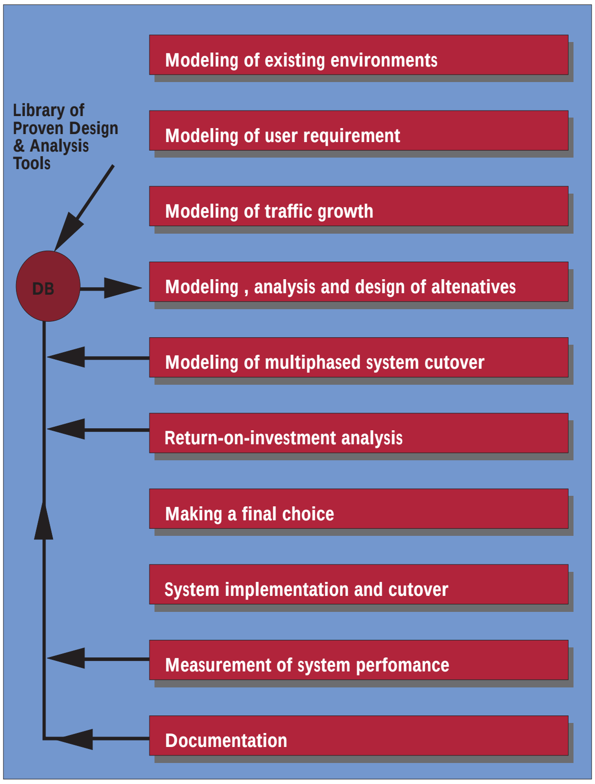

Fig. 2: Life cycle of a network system

At present, large discrete systems are being afflicted with too many design and traffic variables. In most cases, approximate analytical tools will generally yield more meaningful results than other methods, considering cost and time constraint.

CONCEPTS OF PROTOCOL / SYSTEM PERFORMANCE

Performance of a network system generally deals with cost, throughputs, quality-of-service (QOS), and grade-of-service (GOS). Cost of a system should be divided into certain major components such as transmission, Network Management Control and hardware. Experience has shown that transmission costs are generally the predominant part of the total cost.

System throughput measures the overall capability of the system in terms of the maximum number of transactions that can be handled in one unit time. Generally, it refers to the number of average input that can be handled in one second within a busy hour. Quality-of-Service deals with performance issues such transmission quality, voice quality at the receiver, length of error-free periods, average bit-error-rate (BER), system reliability and system connectivity. Grade-of-Service deals with the degradation in service caused by contention for critical resources when all of those resources are functioning.[4]

THE KEYS TO EFFECTIVE SIMULATION

The most important key to effective network simulation is to have a valid representation of the network topology and traffic. Collecting data from lab trials and/or a production network is essential. Then, an analysis of the current traffic will allow us to focus our simulation on a portion of the network.[5]

EXISTING SIMULATION SOFTWARES

Currently R&D Telekom is using OPNET and BONeS as a simulation tool. OPNET is an engineering system capable of simulating large communication networks with detailed protocol modeling and performance analysis.[6] **Fig. 3** shows a model structure with OPNET. Models built with OPNET are hierarchically structured. At the top is the network level, which is constructed from the node level, which in turn is made from the process level. At the lowest level the process domain is structured as a finite state machine. FSM allows users to specify the relation between single states and their transitions and the same can be programmed with C language.

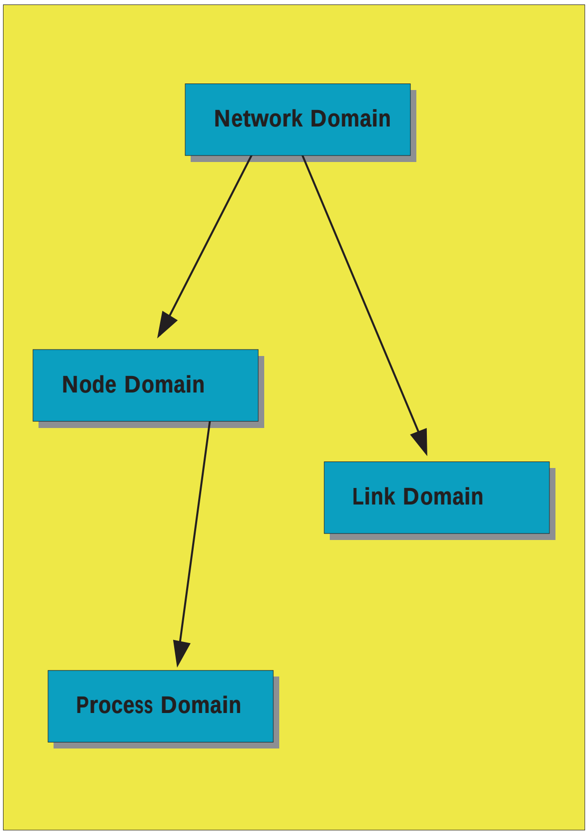

Fig. 3: Model Structure with OPNET

Processes that were specified in the process domain, different source and destination modules offered by OPNET as well as data generation and queues can then be grouped into nodes in the node domain. Nodes can be connected with each other to build up different network architectures in the network domain.

Network level may consist of none or more subnets, and into these subnets there may be any number of further subnets. In this way OPNET can easily represent the hierarchical structure of network such as the public telephone system, which may be made up of a number of local exchanges, which are then connected to a regional exchange. A number of these regional exchanges then go on to connect to a national exchange and this national exchange in turn links up to an international exchange.

At the Node level processes that happen inside a node can be as follows, while a signal being generated, this signal it is then segmented with a header added to it, and finally routed.

Process level allows the designer to create processes required for use in process models. These can consist of processes such as reading in a data stream, counting up to 48 bytes and then segmenting it and forwarding it to the next process, or using a simple sink which reads in packets from a data stream, and then destroys them.

SIMULATION VALIDITY

Some specific suggestions to help make sure simulation is valid:

1. Validate the model against the network. It does not matter how accurate the simulator is if the traffic and topology do not represent the network. Validation is a continual task and is used to confirm the validity of the results or identify an anomaly.
2. Capture traffic over appropriate time periods. Client/server traffic models can be captured based on the conversion pairs imported from any network protocol analyzer. It is important to capture over an appropriate time period. The captured traffic indicates the average rate of data transfer in each direction over the measurement interval.
3. Run the simulation long enough. If it is not run long enough the statistical results will not be accurate. Generally it should simulate long enough so that the simulation reaches steady state and simulates a representative traffic sample after it has reached steady state.[1,2] A steady-state is arrived at when the queues are filled up to their normal operating point. (When a discrete-event simulation starts all queues are empty).

4. Simulate several different scenarios. Due to the random nature of user activity, any time a network that is affected by random usage can be modeled an average case, perhaps an extreme worst case, probably a heavy load that is likely to occur at the beginning or end of a month or quarter.

CONCLUSION

Simulation thus is a powerful tool that can be used in the planning and design of telecommunications networks. Its significance is made much greater today with the advent of multimedia services which requires complex network to support these services. It is imperative therefore, to understand the workings of these networks prior to their being commissioned in order for the services to be delivered within or exceeding the QoS level as agreed with the customers.

It is with this view in mind that the Network Simulation Unit is currently developing expertise in the area of network simulation. Apart from the computer simulation approach, the Unit is also developing expertise in carrying out lab testing as a complementary factor. With this combination, the unit will be able to provide a complete service in terms of providing simulation solutions to network design problems.

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BIOGRAPHY

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A NOVEL FABRICATION TECHNOLOGY FOR MICROWAVE ACOUSTIC DEVICES: PART I - THIN FILM ACOUSTIC FILTERS AND RESONATORS

Zaiki Awang

ABSTRACT

This series of articles describe a new technique of fabricating thin film bulk acoustic wave resonators using sol-gel technology. Fully compatible with semiconductor processing, this technique has attracted a lot of interests owing to its capability of producing high quality thin coatings at low sintering temperatures, a feature particularly useful for GaAs monolithic microwave integrated circuit (MMIC) processing where temperatures of the order of 700 - 800º C cause outdiffusion of Ga and/or As, which in turn damages existing devices fabricated on the wafer.[1] In the first part of this series, a historical development of acoustic wave devices is made. Various acoustic devices, the types of transducers used and their fabrication methods are discussed, with the primary criterion of applications in the microwave frequency regime. Comparisons are made between conventional fabrication methods and the sol-gel technique, in particular on how the work will contribute to microwave acoustics technology. In view of the potential of integrating sol-gel derived acoustic wave devices with MMIC, a survey of various MMIC components currently in use is also made.

INTRODUCTION

All materials support the propagation of acoustic waves. Depending on the particle motion with respect to the direction of propagation, both longitudinal and transverse modes are possible. Fluids support only longitudinal waves whereas both longitudinal and transverse waves are transmitted in solids. In addition to these modes which take place in the bulk of the material, there also exist surface waves. These modes form the basis of operation for modern surface acoustic wave (SAW) and bulk acoustic wave (BAW) devices.

Acoustic wave components are used in many electronic systems, particularly in communications and radar. It is estimated that about half a million SAW filters are manufactured annually world wide for use in television sets. In a microwave acoustic device an electromagnetic signal is converted into an acoustic signal through the phenomenon of piezoelectricity. Due to the fact that the wavelength of acoustic waves in a solid is about five orders of magnitude smaller than that of electromagnetic waves, significant reduction in device size for comparable functions are thus possible. The possibility of size reduction available with acoustic components make them highly popular for use in high frequency integrated circuit technology.

Historical Development of Acoustic Wave Devices

The use of SAW devices in electronic circuits was first considered in the early 1960s. The progress of surface wave devices increased tremendously with the invention of interdigital transducers (IDT) by White and Voltmer.[2] In a SAW device, transducers of equal width placed a quarter-wavelength apart are deposited on a piezoelectric substrate. Electrical signal is applied to IDT which in turn generates acoustic waves in the substrate through piezoelectricity. The frequency of operation is given as by $f = v/\lambda$ where v is the surface wave acoustic velocity, dependent on material, orientation and direction of propagation. The ‘λ’ is the wavelength of the acoustic waves in the medium. Progress in photolithographic techniques employed in the microelectronic industry enabled smaller IDTs to be fabricated, thus allowing operation at higher frequencies, a matter of paramount importance to the communication engineer in any effort order to increase the capacity offered by a communication link.

The possibility of integrating acoustic and other electronic devices on a semiconducting substrate is of great interest. In addition to size reduction, various signal processing functions are possible only with acoustic devices. The prospect of fabricating acoustic components with other electronic devices on a common semiconductor substrate thus presents an almost endless list of possibilities to the integrated circuit designer. To date SAW devices have been successfully integrated with Si and GaAs integrated circuits and the same can perform a host of functions ranging from bandpass filter to tapped delay lines and oscillators.[3,4,5]

Comparison of Acoustic Wave Devices

The fact that surface waves propagate on the surface of a solid implies that the waves are accessible for signal processing purposes along their entire propagation path. This is in contrast to bulk waves which are only accessible at the ends of a piezoelectric crystal. The ability to sample surface waves simultaneously along their path results in various signal processing capabilities of SAW devices that are not possible with BAW components. In this, respect SAW devices are more versatile than their bulk wave counterparts. Owing to the method of wave propagation however, surface wave devices are more susceptible to ageing, whereas bulk waves which are confined in the bulk of the material are less sensitive to ambient conditions.

A detailed study of the use of acoustic devices in the generation of microwave frequencies has been made by Gerber et. al..[6] The results of the survey are depicted in **Fig. 1, Fig. 2** and **Table 1**. **Fig. 1** shows the frequency attainment of the devices over time. Clearly due to developments in photolithographic techniques the IDT frequency limit increased at a rate of about ten times per decade. The centimetre lengths required of SAW filters near 100 MHz made them rather bulky at low frequencies. Hence, BAW devices utilizing plate resonators and oscillators are predominant in the region up to approximately 50 MHz, the upper frequency limit here is due to limitations with the standard plate lapping and polishing methods. Chemical etching and ion beam milling can reduce the BAW plate thicknesses further, bringing the operating frequencies to a few hundred MHz. Higher operating frequencies up to 1 GHz are possible with BAW devices if they are operated at the higher overtones (these are called high overtone bulk acoustic wave resonators, HBAR) but at the expense of lower electromechanical coupling, which results in a reduction of the bandwidth. The HBAR together with thin film bulk acoustic wave resonators (TFR) and composite thin film resonators extend the operating frequencies further into the microwave region. It is due to this reason and their compatibility

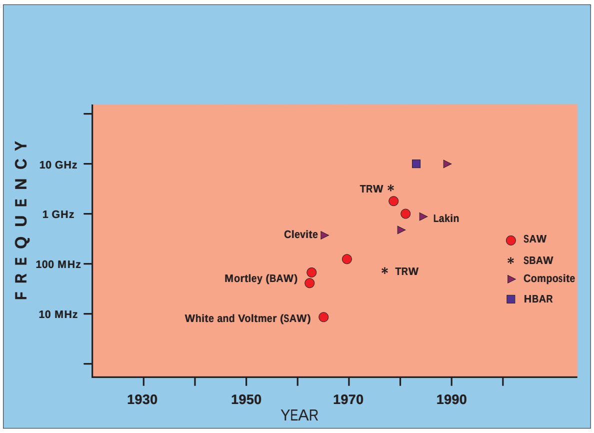

Fig. 1: Progress of acoustic wave device operating frequency with year[6]

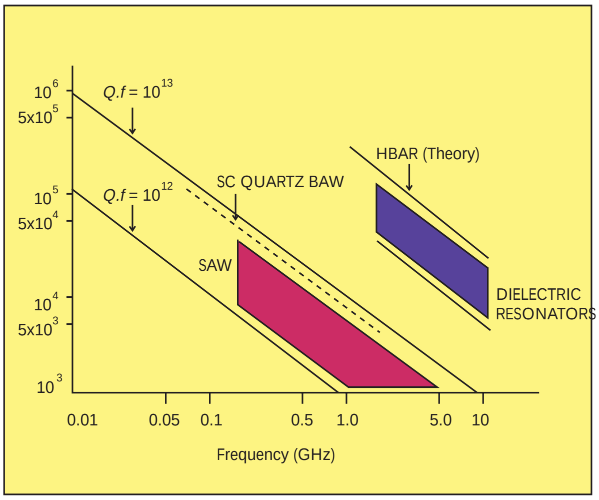

Fig. 2: Measured Q values for various acoustic wave devices as a function of frequency.[6] The values shown are for SC cut quartz BAW, dielectric resonators for DRO applications and the range of observed values for SAW and HBAR

Technology	Frequency	Q.f	Short-term Frequency Drift	Long-term Frequency Drift	Advantages	Disadvantages
Single Crystal BAW Resonator Oscillators	100 MHz - 1.5 GHz	0.07×10^{12} to 3.8×10^{13}	5×10^{-9} to $<10^{-11}$ per sec	5×10^{-6} to $< 5 \times 10^{-7}$ per year	Q about 1.5 times larger than SAW resonators	Resonator very fragile
Composite BAW Resonators	1 GHz - 10 GHz	$> 10^{13}$ Potential Q ten times that of quartz	1 ppm per °C Better than AT-cutquartz for Si substrate		Not restricted to piezoelectric material. Crystals with very high Q can be selected	Multi-resonance very close together
SAW Resonators and Resonator Oscillators	100 MHz - 1 GHz	3.7×10^{12} to 8×10^{12}		$< 2 \times 10^{-6}$ per year	Random fluctuations less than for delay lines	Limited to less than 1.5 GHz
SAW Delay Line Oscillators	100 MHz - 1.4 GHz	0.6×10^{12} to 2.8×10^{12}	1×10^{-9} per sec	$< 2 \times 10^{-6}$ per year	Respectable FM capability, higher power handling	Random fluctuations larger than for resonator
SBAW Oscillators	100 MHz - 5 GHz	2×10^{12} to 11×10^{12}	Temperature coefficient similar to bulk modes	2 - 10 ppm per month	Higher frequencies than SAW. Smaller sensitivity to surface defects	Higher insertion loss

Table 1: Comparison of acoustic wave devices

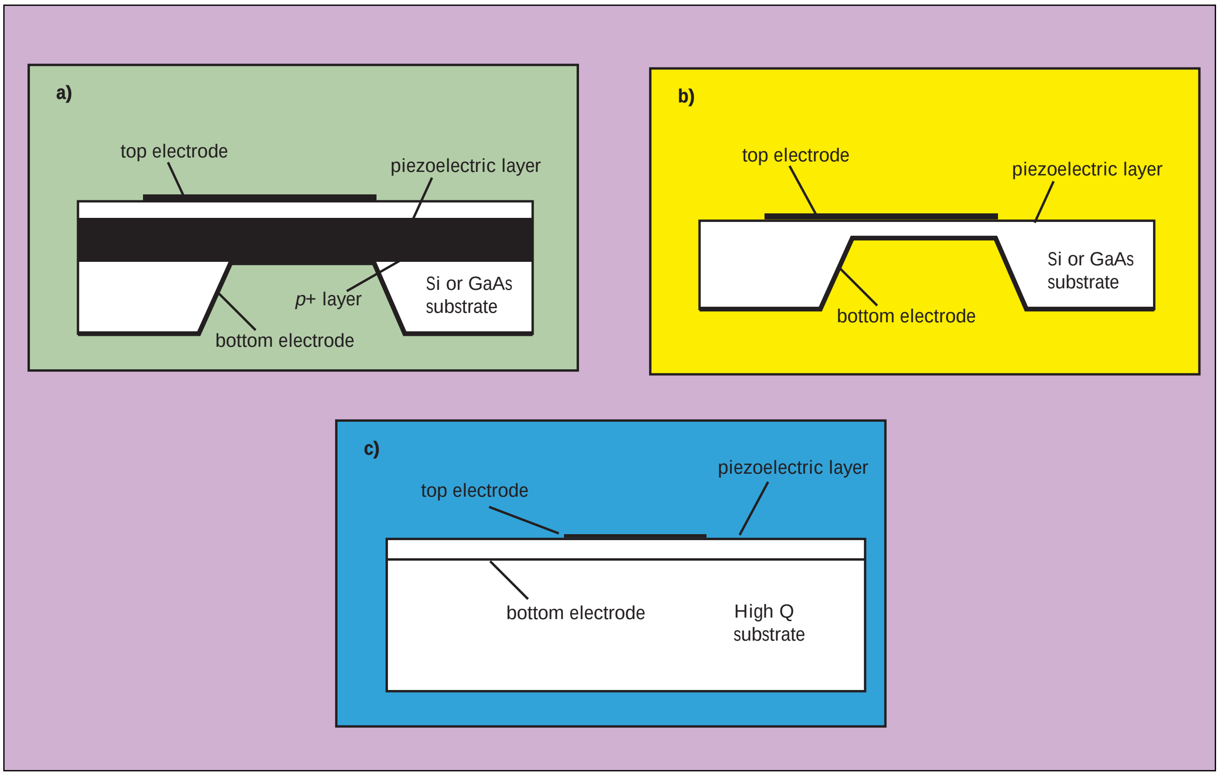

Fig. 3: Cross-sectional views of
a) a composite thin film bulk acoustic wave resonator
b) an edge-supported thin film bulk acoustic wave resonator (TFR) and
c) a high overtone bulk acoustic wave resonator (HBAR)

with integrated circuit processing that they are chosen to be the subject matter of this research. **Fig. 3 (a), 3 (b)** and **3 (c)** depict the various configurations of TFR and HBAR.

Fig. 2 delineates measured Q values of the various acoustic devices. The product Q.f is used for comparison because Q varies inversely with frequency as a result of propagation loss. From the figure it can be seen that BAW devices exhibit higher Qs than SAW devices. In a study carried out by Lakin et. al. it was found that acoustic filters based on BAW devices are also smaller and exhibit lower insertion loss than SAW filters.[7] The result of this study is plotted in **Fig. 4**.

With the limitations of SAW devices at high frequencies, considerable interest has been shown on shallow bulk acoustic wave (SBAW) devices. Used in conjunction with oscillators they offer frequency generation up to 4 GHz directly, and up to 12 GHz by use of harmonics and/or low order multiplication. Similar to bulk waves, shallow bulk waves can be designed to travel almost parallel to the surface using appropriate IDT configuration and suitable substrate material orientation. There are several suitable orientations of quartz that satisfy this condition and so most work on SBAW to date has been on quartz. Designs based on ST-cut quartz for example offer frequency of operation 1.6 times the corresponding SAW frequency for a given IDT.[8] While SBAW devices seem promising however, quartz is not compatible with integrated circuit processing. Owing to this, monolithic integration of SBAW devices with electronic components has not been demonstrated to date.

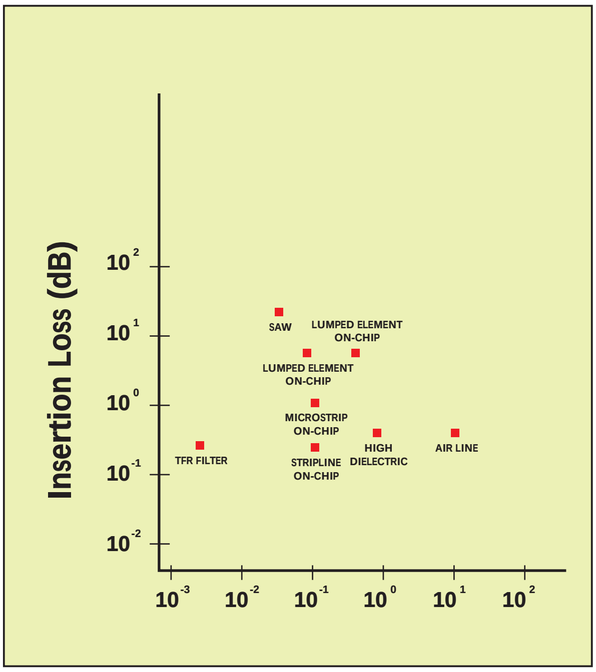

Fig. 4: Comparison of performance and size of 2-pole filters constructed using available filter technologies for use in the 1-2 GHz frequency range

Based on the above survey it is clear that TFR offers the highest potential for operation at microwave frequencies and was thus chosen for this research. Coupled with high Q and low insertion loss, they make excellent candidates for implementing MMIC compatible microwave acoustic filters and frequency control elements.

THIN FILM PIEZOELECTRIC TRANSDUCERS

Conventional low frequency bulk acoustic resonators are fabricated using piezoelectric crystals, the thickness of which determines the resonant frequency. Practical difficulties of lapping the crystals to the required thickness restricts their operation to frequencies of about 100 MHz. For higher frequencies, thin piezoelectric films deposited on a resonant piece of substrate are employed. The films act as transducers which generate acoustic waves into the substrate, the latter acting as a resonance cavity. In this case the substrate and film thickness determines the operating frequency. The films are usually of the order of a few microns thick and with substrates chemically thinned down to about the same thickness, operation at a few GHz is possible.[9,10,11,12] The choice of substrate is dictated by the ability to promote growth of the films. Commonly used materials include quartz, sapphire and glass but the more exciting ones are Si or GaAs since this option opens the way for integrated circuit implementation.

Various thin piezoelectric films are available, the most common ones are ZnO, AlN, CdS and the ferroelectric titanates consisting of lead titanate ($PbTiO_3$) and lead zirconate titanate ($Pb_{1.0}Zr_xTi_{1-x}O_3$), usually known by its industrial name PZT. ZnO, AlN and CdS films are normally grown using vacuum deposition and rf sputtering, while ferroelectric films have been prepared by a variety of methods as illustrated in Fig. 5.[13] Although some degree of success has been obtained using these techniques,[14,15,16,17] they suffer from high deposition temperatures, slow deposition rate and poor stoichiometry control. The elevated temperatures are necessary to promote crystal growth and are usually of the order of 500 - 900°C, figures which are not particularly suitable for GaAs technology. Lower deposition temperatures are possible but even with a low 200°C deposition using dc magnetron sputtering, post-deposition annealing at 550 - 750°C for durations up to 10 hours are still required to yield films of the right crystallinity and composition.[18] Coupled with slow deposition rates (typically 0.1 - 2 mm/hour for PZT for example), these methods have not really been utilized in integrated circuit processing.

Higher deposition rates and better stoichiometry control are possible with chemical vapour deposition (CVD) and metal organic chemical vapour deposition (MOCVD) but very high temperatures are still required (700 - 800°C). MOCVD in particular requires highly volatile organometallic precursors which can be both toxic and costly.

It can be concluded that although promising as strong piezoelectric materials, ferroelectric ceramic thin films have not found application in integrated circuit applications due mainly to the difficulties encountered in synthesizing films of the required quality. Alternative methods of growth are therefore required to exploit their enormous potential for use in the semiconductor industry. Sol-gel, with its favourable processing conditions, has attracted a lot of interest in sequence.

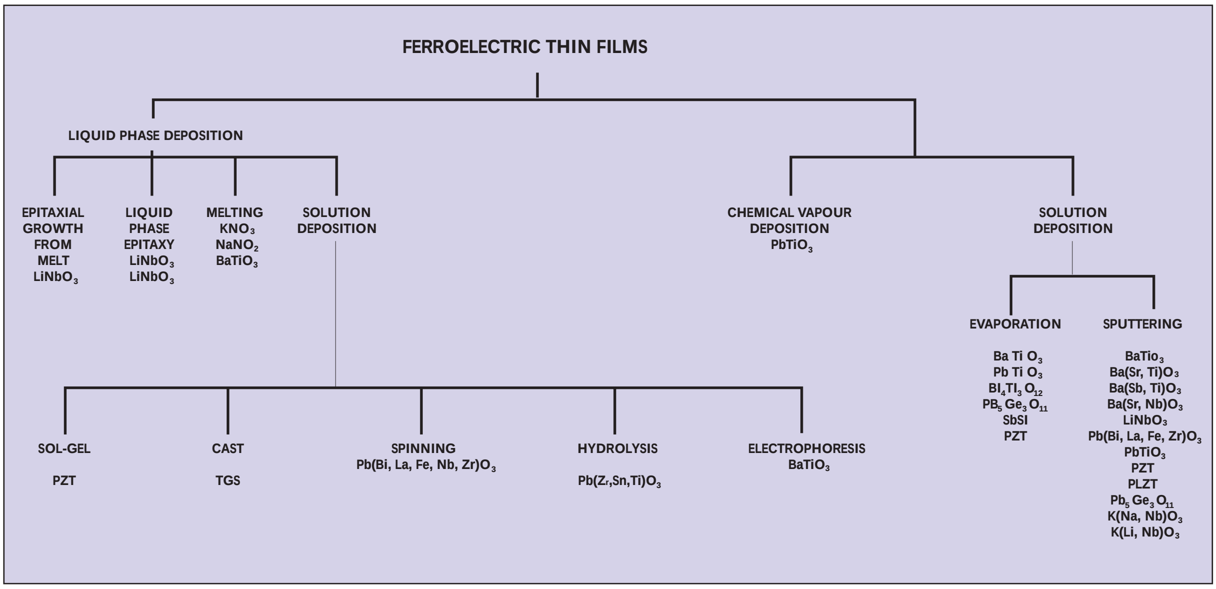

Fig. 5: Deposition techniques employed in the fabrication of thin ferroelectric films

MONOLITHIC MICROWAVE INTEGRATED CIRCUIT COMPONENTS

The concept of MMICs was first explored in 1965 by Hyltin.[19] However poor quality semi-insulating properties offered by Si substrates did not allow fabrication of reliable circuits. Mehal and Wacker in 1968 reported an integrated 94 GHz receiver front end implemented on a semi-insulating GaAs substrate which utilized GaAs Gunn diodes and Schottky diodes.[20] In 1976 Pengelly and Turner fabricated monolithic broadband GaAs MESFET amplifiers and since then GaAs FETs have emerged as prime contenders for MMIC technology.[21] Key advantages of MMIC technology include improved reliability and reproducibility, broadband performance, circuit design flexibility, multifunction capability on a single chip, small size and low cost. The monolithic approach also has the advantage in that parasitic effects are practically eliminated since the active devices are an integral part of the semiconductor substrate. With parasitic effects being more significant at higher frequencies, this advantage makes MMICs attractive for microwave and millimetre wave applications.

A brief survey of approaches used in MMIC design follows below. The objective of this survey is to show in perspective as to how this research can contribute to MMIC technology. The performances, shortcomings and future developments of existing MMIC components that can be replaced by sol-gel films are also discussed.

MMIC Capacitors and Inductors

Typical single loop inductor values for monolithic circuits rarely exceed a few nH while up to 50 nH can be realized with multi-turn spiral inductors fabricated on GaAs. Higher values are difficult to realize in strictly lumped form because of inter-segment fringing capacitance and shunt capacitance-to-ground. Nevertheless the inductor can be used throughout the frequency range provided the parasitics are accounted for. Unfortunately the exact parasitic values are seldom known in advance, and corrections made in later design iterations can become costly.

MMIC capacitors may take one of two forms - interdigitated or overlay. The latter employ a thin dielectric film such as SiN or polyimide and are popular for low impedance circuitry and bypass and blocking applications requiring capacitances from a few pF up to about 40 pF. Interdigital capacitors do not use a dielectric film but work on the principle of electrostatic coupling via the substrate. They are generally more suitable for high impedance matching circuits demanding low capacitance values i.e. less than 1pF.

MMIC capacitors are invariably low Q elements due to lossy characteristic of thin dielectric films. As a result, Q values lower than 50 are typical at 10 GHz. Resonant circuits and filters formed by these elements therefore exhibit poor Q values. Filters made by transmission line sections may give satisfactory performance but their size is too large even when fabricated on high dielectric constant materials.

MMIC Oscillators

Both fixed and variable frequency monolithic oscillators have been implemented. Joshi et. al. reported the first monolithic oscillator which used a FET in common gate configuration.[22] The design utilized a gate feedback loop employing a single loop inductor and an interdigitated capacitor. The chip measured 1.8 X 1.2 mm^2 and gave an output power of 8 mW at 13 GHz.

Off-chip dielectric resonators used together with capacitive series feedback networks are also employed in fixed frequency MMIC oscillators. Due to high Q-factors and good temperature compensation possible with these resonators, highly stable oscillators have been reported. In a design reported by Hori *et. al*. the resonator was mounted on an alumina substrate and coupled to a microstrip line terminated in 50 Ω.[23] The frequency drift was 1.2 ppm/°C from -40 to 80°C. Dielectric resonators however are bulky and are not suitable for integrated circuit implementation. The oscillator reported by Hori here measured 2 X 2 cm^2 when combined together with the dielectric resonator.

Variable frequency MMIC oscillators usually employ varactor diodes to provide a tuning capability over a desired frequency range. A typical voltage controlled oscillator (VCO) chip includes microwave elements as well as biasing circuits. A 4 - 7 GHz VCO employing a 1200 micron gate width MESFET would typically measure 3 X 3 mm^2.[24] It should be noted however that most MMIC oscillators, especially VCOs, are designed using a semi-empirical approach. Despite various efforts in VCO modelling it is still difficult to predict the output power.[25,26,27] For an MMIC designer this is unacceptable as design and process iterations are costly. Current research trends in this area focus more on design tool implementation to predict power, bandwidth, harmonic level and linearity.

MMIC Receivers

MMIC components described in previous sections function at the lowest level of complexity. At higher level, these components are integrated, enabling various functions to be carried out. At this level the deficiencies of monolithic circuits are more severe due to the lack of high Q resonators. The case of an

MMIC receiver demonstrates this point. Workers at LEP for example demonstrated an experimental monolithic receiver chip intended for direct broadcast satellite applications in the 11.7 - 12.2 GHz band.[28] The chip measures 1 cm^2 which is large by integrated circuit standards. Consisting of a two-stage low noise MESFET amplifier and a dual-gate FET mixer/oscillator, the circuit size increased tremendously when an off-chip dielectric resonator was used to stabilize the oscillator. At the present level of technology there appears to be no solution to this problem. A multi-chip approach whereby the receiver is not fabricated on one chip, is usually a preference in a mode to increase the overall yield.[23]

Prospects of Sol-Gel Technology at Microwave Frequencies

It can be summarized that at the present state of MMIC development there are certain components which are difficult to realize with the same performances as their hybrid counterparts. Complications occur in the uhf/lower microwave range (where cellular, telemetry and navigation systems are expanding) where the size of these elements are too large even when realized on high dielectric constant substrates. Two circuit components which have not been routinely achievable on-chip are high Q filters and resonators. Presently if narrowband, fast transition or tightly specified characteristics are required, a stand-alone filter or resonator fabricated from different materials is used, usually based on SAW devices, cavity or dielectric resonator. Off-chip dielectric resonators and filters are large, complex and are not compatible with integrated circuit processing. Crystal resonators, SAW resonators and SAW filters are also large relative to MMICs. The fact that they are constructed from special piezoelectric materials means that they cannot be integrated on-chip. TFRs are completely compatible with MMIC processing. They offer significant size reductions while at the same time promise high Q performance and exhibit excellent frequency stability.

Sol-gel technology revolutionized the method of preparing ceramic materials. Its capability of synthesizing thin ceramic films at lower sintering temperatures opens up the possibility of employing this method in integrated circuit fabrication process and provided the impetus for this research. In sol-gel processing the precursors are mixed at the molecular level (the sol), thus allowing ease of stoichiometry control and the possibility of lower annealing temperatures. The sol is then spun on semiconductor wafers using a commercial photoresist spinner. The whole process is carried out in a clean room. The coatings are heated rapidly to give highly crystalline, large area thin films (the gel). Due to the nature of sol-gel processing it is possible to grow high dielectric constant films having superior ferroelectric/piezoelectric properties. These films will find wide applications in the high frequency range either for use in acoustic devices or in thin film MMIC elements. The integration of sol-gel films with active devices on a common substrate will therefore make a significant impact in MMIC technology. To date highly homogeneous lead titanate and PZT films of thicknesses ranging from 0.5 - 1.0 mm have been fabricated on Si and GaAs substrates by the author. These films were implemented as TFRs and resonances up to 5 GHz have been observed experimentally, details of which have been reported elsewhere.[29,30,31,32,33,34] The utilization of sol-gel technology in the microwave regime is relatively new and to the author's knowledge this is the first such attempt. Research is currently in progress to improve on-wafer calibration on order to yield more accurate device characteristics.

CONCLUSION

A detailed overview of microwave acoustic devices has been poignantly discussed in this article. In particular it was pointed out that film bulk acoustic wave devices exhibit superior performance at these frequencies compared to their surface wave counterpart. Current fabrication procedures of thin film acoustic wave components were discussed at length and comparisons between them were made to the new wet chemical method method of sol-gel. The method is completely compatible with MMIC technology and should open the way for large scale implementation of thin film acoustic devices for use in cellular communications soon in due course.

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BIOGRAPHY

Zaiki Awang joined Institut Teknologi MARA in 1985 as a lecturer and is presently serving in the capacity of Deputy Dean (Resources) at the Faculty of Electrical Engineering. He received his tertiary education from Portsmouth University where he did his Masters in Microwave Engineering and subsequently obtained a PhD in Electrical Engineering from Leeds University. His doctoral research investigated the possibility of integrating thin ferroelectric films with active devices on GaAs substrates for possible monolithic microwave integrated circuit implementation.

Dr. Zaiki Awang has written well over 30 technical papers. His areas of interest are rf/microwave subsystem design, monolithic microwave integrated circuit (MMIC) fabrication technology with specific specialisation in GaAs processing, on-wafer device measurement and calibration, high speed/high frequency digital circuit design and thin ferroelectric/piezoelectric films for high frequency applications. He initiated research in rf/microwave/millimetre-wave sub-systems at the Faculty and designed the curriculum for RF Design subject, the only one of its kind offered by an institution of higher learning in Malaysia that specialises in rf/microwave sub-system design. The subject has been offered successfully for the past 8 years and is offered to final year Institut Teknologi MARA undergraduate students majoring in Telecommunications.

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By integrating virtual-world information technology and electronic commerce capabilities with real-world physical delivery of products through its air and ground transportation network, FedEx sought to exploit the new opportunities emerging in the digital economy. Through a process of strategic acquisitions in late 1997 and early 1998, FedEx consolidated its position as a leader in the express package delivery business.Â @article{Rao1999BuildingAW, title={Building a World Class Logistics, Distribution and Electronic Commerce Infrastructure}, author={R. Bharat Rao and Ziv Navoth and Mel Horwitch}, journal={Electronic Markets}, year={1999}, volume={9}, pages={174-180} }. R. Bharat Rao, Ziv Navoth, Mel Horwitch. Published in Electronic Markets 1999. Chapter 3: Digital Infrastructure Digital Connectivity in Malaysia Malaysia underperforms in the provision of high-quality, fixed-line infrastructure Regional disparities Underlying Challenges Market structure State-level regulation of connectivity infrastructure Recommendations.Â Figure 1.2 Most people in Malaysia are connected to the internet or have a mobile cellular subscription 13. Figure 1.3 Malaysia has a sizeable ICT sector compared to OECD economies due to the relative prominence of ICT manufacturing and telecommunication sectors. 15. Figure 1.4 Business establishments engaged in e-commerce are much bigger than average. 17. Figure 1.5 Digital technologies create both benefits and risks.