Broadband Implementation Of Circuit-Switched Services

An Architectural Overview

Adaptive Network Solutions

Overview

The migration and implementation of telephony services onto packet- or cell-based networks has begun. There are specific benefits associated with moving to a broadband network, some of which are explored in this paper. These benefits include lower costs per call, increased flexibility and guaranteed scalability. A logical first step is the interconnection of local exchanges using a broadband network — in effect, implementing a broadband tandem layer.

In addition, there is an opportunity to maximise those benefits by using a design architecture that utilises and exploits the advances that have been made in both telecommunications and data communications over the last decade, namely modularity, distribution and intelligence. Future networks are being designed to meet projected increases in traffic volumes, to have the ability to deploy new services quickly and to be future-proofed. Operators who are now investing in an efficient, scalable network infrastructure will be best positioned for the future.

Future Networks

In the not-so-distant future, operators will face massive growth in bandwidth requirements from all types of customers — residential subscribers, business subscribers and interconnect partners — which will have a profound impact on network planning. Changes resulting from deregulation and competition, such as number portability, carrier pre-select and price erosion, are additional criteria to consider in the planning process. Operators today need to make critical business choices with the view to reduce costs and maximise revenues.

The new network architecture must be capable of dealing with the pressing problems that exist today with a framework that will provide for the future. This paper explores the benefits of the new network architecture, while focusing on interconnecting local exchanges via a packet- or cell-based network and the combined principles of distributed computing from the data world and reliability from the telecommunications world.

Sprint plans to carry all of its traffic, voice, video and data over an ATM network, an approach that will cut the cost of delivering a voice call by 70 per cent. The flexibility and scalability in the technology and architecture in Sprint's approach assures the ability of its network to meet future needs.

Design Parameters. State-of-the-art network design should incorporate both modularity and distributed computing, and network intelligence. These parameters are interdependent, provide specific benefits and are mandatory to effect a network that will survive and grow as traffic and services grow and evolve.

Modularity and Distributed Computing

Modularity, one of the key design parameters, allows functional elements to evolve separately in terms of their service capabilities, performance and size, thereby ensuring that equipment is optimised in architecture and use. Decentralising processing and computing capabilities within the architecture is dependent on a modular model.

In practice, this would mean that network elements are highly scalable and can be deployed using a distributed architecture in an operator's network, providing functionality where and when required.

In a stored program control (SPC) switch architecture, for example, the main functions of the switch are to process calls, provide termination for circuits and provide service switching point (SSP) and/or signalling transfer point (STP) functionality. Physical separation of these functions and the distribution of processing power in the network allow for greater flexibility and scalability. Implementation of this service architecture is compatible with the leading trends in information technology, including client/server principles and application-function distribution. Increased flexibility and ease of management are other additional benefits, particularly if the architecture integrates with existing management information systems and within the telecommunications management network (TMN) architecture.

Enhancing the modular architectural model for services and feature-rich call processing is achieved by incorporating network intelligence.

Network Intelligence

Network intelligence is implemented using intelligent networking (IN). The two advantages of intelligent networking — the separation of the control network from the physical network and the ease of implementation of new services — will accelerate the deployment of new and differentiated services by operators worldwide. Operators that deploy IN-based platforms will benefit by maintaining or improving their competitive positions, creating new sources of revenue and ease of compliance with government regulations, such as implementation of number portability.

Network intelligence allows the operator greater flexibility in implementing services by the disassociation of messaging and routing information from the switch through the use of dedicated databases. What this means is that call control, service provisioning, signalling and billing are performed using dedicated network elements within a distributed computing architecture.

Network planners are facing a challenging and exciting task, designing and building new networks with the latest in equipment and architecture design, as well as advances in technology that combine faster processing speeds with reduced cost, power consumption and space requirements.

Packets and Cells

Increasingly, operators install packet- and cell-based networks to support data services. Not only are these protocols efficient at carrying data traffic, but they are also equally beneficial in the transport of voice and other switched services. The most obvious benefit in the first instance is the consolidation of multiple services onto a common platform, resulting in savings in equipment, operational and transmission costs. The consolidation and support of services with different quality of service characteristics results in efficient use of bandwidth by statistically multiplexing traffic.

The following attributes of packet- or cell-based networks provide additional advantages when used to implement reliable networks for circuit-switched services:

Flexible bandwidth granularity. The connections can be anything from a few Kbps to hundreds of Mbps, which is more flexible than the rigid granularity of TDM-based networks. Bandwidth is allocated based on user requirements that are identified when setting up the traffic contract.

Virtual connections. Logical and physical virtual connections can be set up to any desired bandwidth.
Dynamic connections. Packet- or cell-based signalling protocols enable switched, as well as management-configured, connections to be made, and also facilitate dynamic bandwidth provisioning in the event of network failure, assuming that fibre and transmission capacity is available.

Migration

The evolution of the telephony network is expected to occur in several phases. There are several good reasons for this — the investment in the public switched telephone network (PSTN) is substantial and the cost of total replacement would put most operators out of business. Full implementation of services and features that exist today on the PSTN requires significant investment and change in network planning to realise the use of a packet- or cell-based infrastructure, therefore, it is best to migrate the simpler services first.

Staged migration also aids the learning curve. Packet- or cell-based networks are highly flexible, and practical implementation provides the best textbook for process and planning re-engineering.

Packet- or cell-based interconnect of local exchanges forms part of a long-term strategy for full implementation of voice and telephony services. Additional service features can be added to the modular architecture and traffic migrated off existing switches. This approach is beneficial for a number of reasons:

- Total cost per call is reduced.
- Tandem switches generally have fewer feature sets and functionality, so replacement is relatively easy.

- Transitioning should have minimum impact on customers.
- Migration is facilitated, as there are fewer test scenarios and potential feature-interaction problems.

PSTN

The PSTN network is an established, researched and optimised infrastructure designed for the transport of circuit-switched calls. It was not designed or constructed for the demand that new services, especially the Internet, are placing on it today.

The network is also under pressure from the growth in enhanced services. These types of services require an increase in the number of signalling messages per call and additional software loads on traditional switches, both of which increase the operating load of the central processors. These increases are resulting in a mismatch between the call processing and port termination capabilities of an exchange.

Finally, growth in telephony traffic and the requirement for interconnection with other licensed operators has exhausted the port capacity of stored program control switches, particularly at the tandem level.

POTS

POTS, or plain old telephony service, is not so plain. Compliance with regulations means that the service must be extremely reliable and guarantee connection in most circumstances — in particular, calls to emergency services (112/999/911). Meeting these criteria has resulted in a network with complex planning and forecasting processes. Redundancy is the keyword: if any element fails, there will be another to back it up and, if not, the service will be restored depending on your service-level agreement. Failure on the operator’s part to deliver reliable voice telephony can result in heavy penalties levied by the regulator, as well as a potential loss of revenue.

Redundancy has a profound impact on network planning, particularly in the core network where local exchanges can be dual- and sometimes triple-homed onto tandem switches (also called trunk and transit switches). If one tandem fails, then the traffic can be sent to the secondary tandem as defined in the routing tables. The tandem switches in their turn are interconnected using a mesh transmission network, where each tandem switch is connected to every other tandem in the network.

Transmission Network

Dimensioning the core transmission network for carriage of circuit-switched traffic during peak busy hours, as well as ensured redundancy, results in severe penalties. For some operators, up to 40 per cent under-utilisation of capacity can occur. This is one of the main drawbacks of the network; capacity that is allocated to a particular service cannot be used for other services even if no traffic is being passed. This inefficiency is compounded when the provisioning granularity in backbone transmission networks is DS3 (45 Mbps) or higher.

In the core transmission network, switches are interconnected using a mesh network, where the number of trunk routes between switching elements is $n(n\text{-}1)/2$, with n being the number of switches *(see Figure 1, TDM Mesh Network)*. In large networks, this results in a high number of trunk routes, *e.g.*, where there are 20 tandem switches, there would need to be 190 trunk routes to fully mesh these switches.

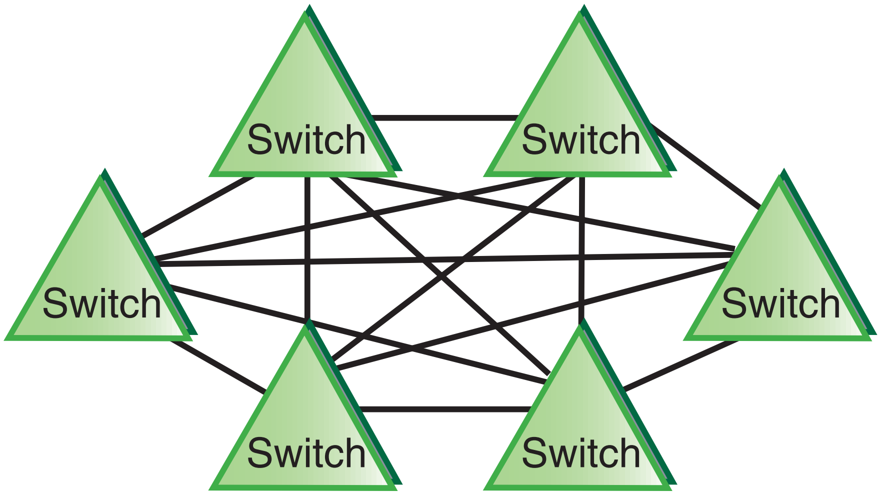

Figure 1: TDM Mesh Network

As each of these 190 trunk routes is dimensioned for peak, busy-hour traffic, there is a lot of capacity lying idle for much of the day.

For sensitive traffic, network resiliency requires the static provisioning of alternate routes to be available in the event of network failure — further adding to the under-utilisation of transmission facilities in the core network.

Relatively new factors to be considered in the allocation of transmission capacity in the network are inter-connection with other licensed operators (OLOs). Managing this capacity is difficult, as the OLO could be using these facilities as either a primary, secondary or tertiary route. This may mean that capacity is allocated, but no revenue is gained from carrying traffic. It is desirable from a revenue point of view to be able to accommodate this traffic; however, managing OLO growth and churn can seriously affect the utilisation on transmission facilities.

Transmission Migration Benefits

Consolidation of services onto a single transmission network achieves economies of scale by using bandwidth more effectively. Bandwidth is shared among applications, increasing utilisation from statistical multiplexing gain where services are commonly mixed in one bandwidth pool. The network becomes more efficient by permitting statistical gain across many more subscribers and services simultaneously.

The ability to reconfigure virtual connections statically and dynamically, on either primary trunk routes or re-routed traffic in the event of network failure, overcomes the inefficiency of having committed alternate routes. This results in a flexible mesh network. In the event permanent alternate routes are implemented, then capacity for those routes can be used for other services in the absence of network failure. In essence, transmission utilisation is enhanced and, as a result, there are significant cost savings.

Switching Network

SPC switches started to be widely deployed in the early 1980s and, other than processor and software package upgrades, have not changed much over the last two decades. In the meantime, there have been dramatic changes in technology. Time division multiplexing (TDM) switch design is limited, and the new telecommunications environment will only increase the demand on processing and port capacity, particularly in the area of new services, *e.g.*, number portability, carrier pre-selection and OLO interconnect.

In *Figure 2: SPC Switch Limitations*, the switch architecture is represented showing the main elements that are physically and logically dependent on each other and where the service creation environment is also dependent on software, processing and memory upgrades on the switch. The design is inflexible and expensive.

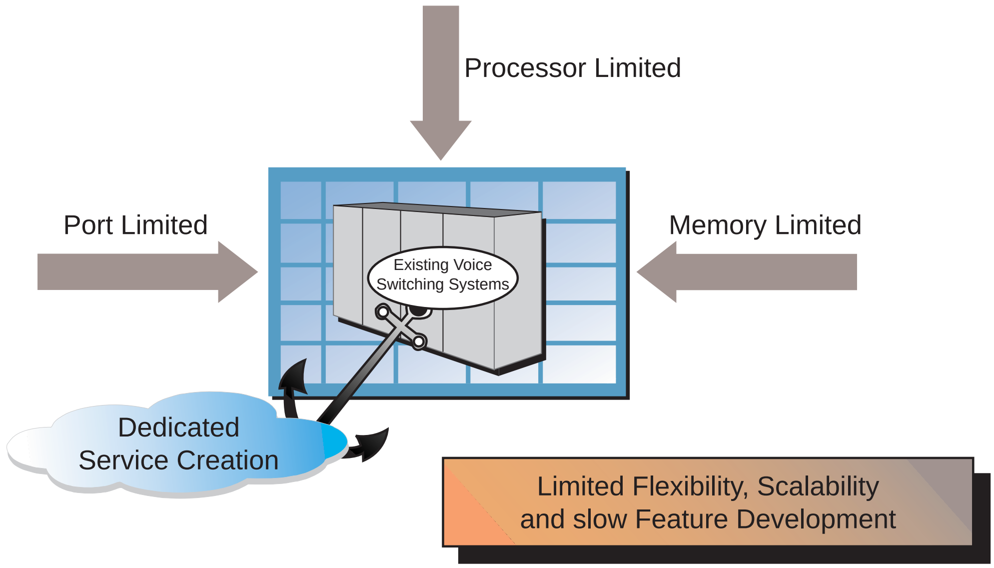

Figure 2: SPC Switch Limitations

A common problem facing large established operators is port exhaust, where implementing the mesh transmission network requires a trunk connection between each switch. Recalling the mesh equation for transmission networks $n(n\text{-}1)/2$, where n is a switch, finite port capacity places an upper boundary on n. There will be an n where it is no longer possible to add another switch to the mesh.

Accommodating additional switching capacity is also complex, as each new switch requires interconnection to all other switches in the mesh network. Again competition and the necessity for interconnection to OLOs has increased the demand for switch ports, usually at the tandem level where most points of interconnect are located.

New features require additional software and an increase in signalling messaging, both consuming finite processing capacity. Services such as 1-800/Freephone place huge demands on signalling messaging and, therefore, processing. It is also a dynamic service, as numbers are constantly added to the database. For most operators, such services are implemented as intelligent overlay networks, providing them with capacity, centralised database operation and the ability to enhance the service, *i.e.,* with time-of-day routing.

Switching Migration Benefits

Packet- or cell-based switching equipment benefits in the first instance from recent technology developments whereas more can be done using less, *e.g.,* processing advances have speeded up transactions, using less power, costing less and requiring less space to serve the same number of customers as a TDM switch.

Port usage is optimised as the capacity of the packet- or cell-based switches is larger and therefore n, the number of switches, is lower. The use of a dynamic routing akin to wide-area port gain also maximises port usage.

Implementing switch functions using a modular, distributed architecture — where switching, adaptation, call control, connection management and databases for special services are coherent logical entities with dedicated processors that can be physically separated — facilitates future seamless growth. The switching architecture is highly scalable.

Physical independence also allows the functional elements to be remotely located, a significant benefit for new licensed operators who want to build up a tandem or toll-access infrastructure over a wide geographic area, but do not want to deploy dedicated expensive switching facilities in each location. A case in point is the carrier that desires presence in fifty serving areas without investing in fifty full-featured switching systems.

Architecture

The functional elements required to implement the interconnection of circuit-switched services via a packet- or cell-based network are illustrated in *Figure 3, Core Packet- or Cell-Based Network for Telephony Services.* The functions are access, transport, media adaptation, switching, management and services.

An absolute requirement is that the service quality must be comparable with that experienced in PSTN today.

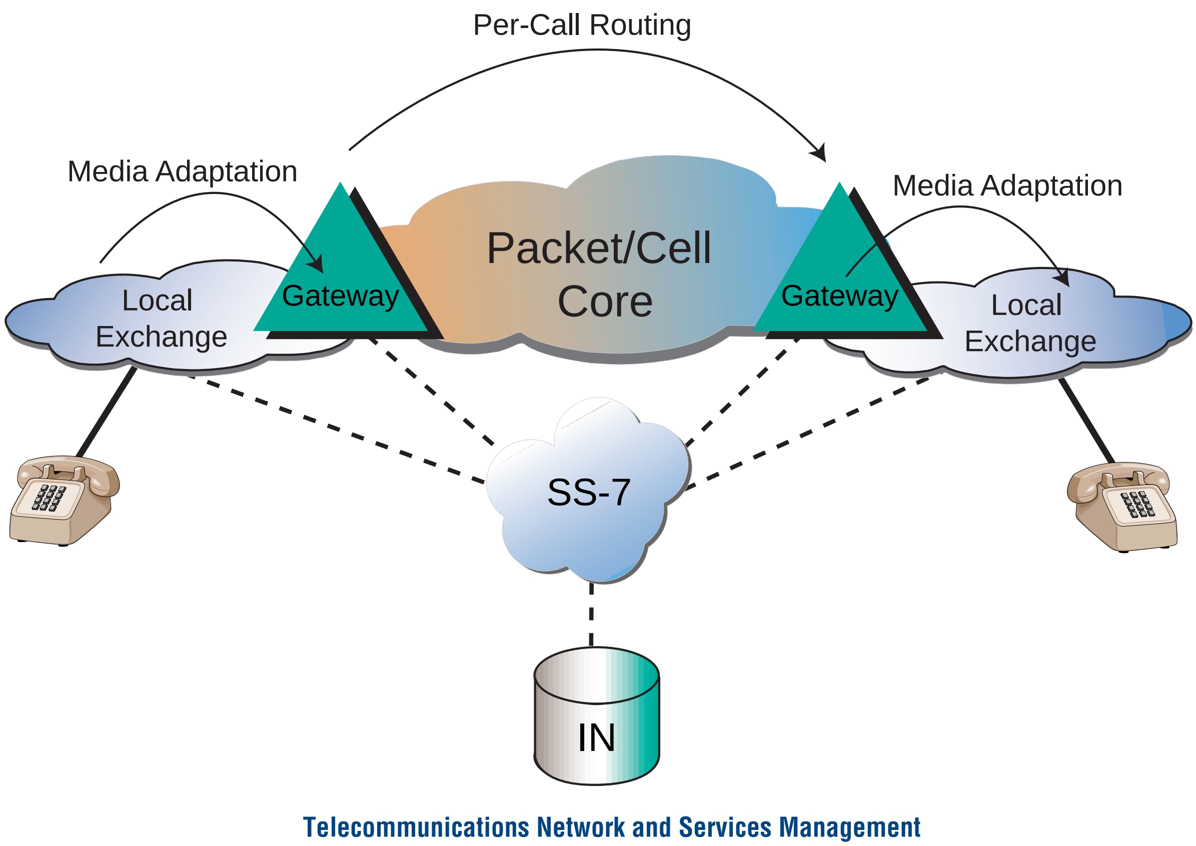

Figure 3: Core Packet- or Cell-Based Network for Telephony Services

In the diagram, the local exchange provides the access point for residential and business subscribers. As broadband networking develops and rolls out from the core, additional capabilities could be accommodated on the gateway for business and residential service provision. The SS-7 network is shown here as a separate overlay network, interfacing with the local exchange network, the gateway and the intelligent network (IN). It is not necessary to have the SS-7 implemented as an overlay, as these messages can be transported using the packet- or cell-based network, providing the gateway has SS-7 termination and origination functionality. However, transport and interconnection of SS-7 messages and gateway messages can also occur through the existing SS-7 network as well.

The gateway is a logical, and not necessarily a discrete, physical entity. The functional elements that comprise the gateway depend on the application and the requirements. In general, the gateway must provide interworking between the TDM and the packet- or cell environment, including protocol and signalling adaptation, and call control. This interworking can be either network or service interworking. Network interworking is the transparent transport of narrowband services and signalling through the ATM network, and service interworking is the mapping of narrowband services and signalling into ATM.

The packet- or cell-based core contains the transmission and switching infrastructure, and all elements are controlled by an encompassing management infrastructure.

Implementation and Benefits

Exchanges can be interconnected using virtual connections over the packet- or cell-based network, which can be either ATM or IP. Immediate benefits over TDM networks are that, outside of the busy hour, other services can burst into pre-provisioned capacity. As with TDM networks, designing networks to work under a variety of failure conditions necessitates the provisioning of redundant routes that, in a packet- or cell-based environment, can be available to other services based on traffic contracts and service-level agreements — an approach that provides a degree of comfort.

Bandwidth savings can be achieved using a mesh consisting of virtual connections that can be dynamically sized and redundant paths that can also be provisioned dynamically. Transmission capacity assignment is flexible, not constrained by the granularity imposed by TDM and synchronous digital hierarchy (SDH), and optimised by the use of statistical multiplexing.

Increased switching capacity reduces the number of connections required across the core to build the mesh; fewer switches are required. Virtual connectivity is provided between every end point in the network.

The technology used to develop packet- or cell-based products is typical of that used in data products and can be more cost effective than existing TDM technology, providing operators with equivalent functionality at a lower price point. As standards for full narrowband-to-broadband interworking, are further developed operators can complete the integration of these networks and fully optimise their resources to both provide new services and further reduce service-provisioning costs.

This architecture is both scalable and distributed, and leverages the PSTN network by employing a solution to mitigate port exhaust and poor bandwidth utilisation on the trunk-switched networks. Implementing a network that incorporates advanced intelligence provides the additional benefits of easing new service deployment, and permits a modular, distributed client-server-type architecture that guarantees future scalability.

Profit Generation

Profit can be derived two ways: cost reduction and revenue generation. So far in this discussion, cost reduction has been the main focus. However, revenue lies in services. It is critically important in the migration and implementation of a new network infrastructure designed to carry operators into the future, that the network accommodate and facilitate the creation of new services. In addition, services migrated onto the new network must perform as well as, if not better than, before. The separation of service creation from switch architecture and the use of an IN model should significantly improve the flexibility and speed at which new services can be deployed.

Transitioning voice services onto the packet- or cell-based network provides incumbent operators with an opportunity to significantly reduce costs today and roll out services and features faster tomorrow. For new licensed operators, particularly those implementing national and global data networks, the ability to offer global voice and business services significantly enhances the service portfolio and, therefore, revenue.

Conclusion

There are strong economic arguments for implementing a packet- or cell-based core for data traffic and, from the issues and discussion presented in this paper, we have seen that there are equally strong arguments for migrating voice and telephony services onto this core network. Interconnecting local exchanges via this network is the optimum solution to address the problems operators are experiencing today within a framework that will continue to be viable for the future.

www.tellabs.com

tellabs®

Corporate Headquarters • 4951 Indiana Avenue • Lisle, IL 60532-1698 • 1.630.378.8800 • Fax: 1.630.852.7346