IP Telecommunications Architecture

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Abstract

The following paper is an introduction to the issue of architectures for IP Telecommunications. Architectures are important because they provide for a set of common terms against which new ideas can evolve. The architecture makes explicit what we are trying to do in an evolving network environment. The architecture is at the heart of a productive discussion and evolution of the system and the embodiment of that system concept.

Contents

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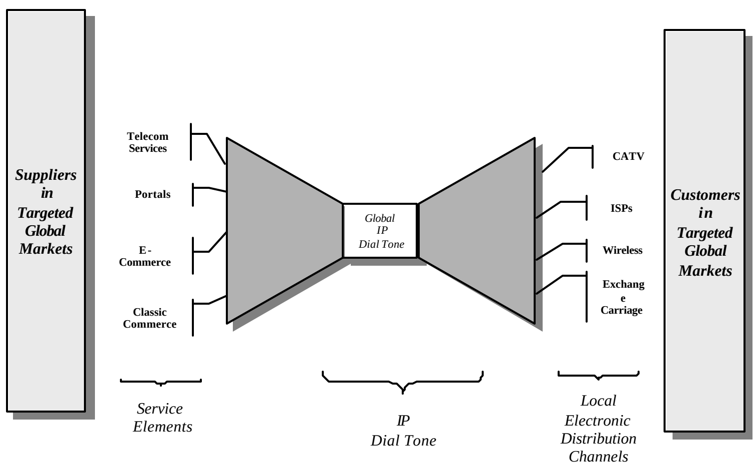
[1] This paper is a working draft and is not for distribution. This paper is not for reference and the contents are subject to change and modification. It is prepared for the MIT Internet and Telephony Consortium Working Group, November, 1999. McGarty is with Telmarc, Zephyr Telecommunications and is a member of the Steering Committee of the MIT Group.

1. INTRODUCTION

The basic concept of this paper is how does one implement, operate, and expand an international or domestic "IP Dial Tone" carrier, providing IP access to a variety of services such as telephony, e-commerce, portals, and more traditional services, via a broad selection of electronic distribution channels, such as local and long distance exchanges, CATV systems, wireless and mobile systems, and ISPs throughout the world. Specifically, what is the architecture for that implementation and how can that architecture and its associated defined terms be used for the purpose of establishing a common international dialog amongst developers and implementers approach the problem from two perspectives; the telecom world and the Internet world.

This concept of IP Dial Tone connects the various value added services through the various electronic media, to the customer base. The architecture is supported by a superior base of operations support systems, including network management, billing, customer care and services, provisioning, global repair and dispatching, and through a global network of the Company's circuits and systems. The following Figure depicts this overall concept. IP Dial Tone may vary from mere telecom services, to e-commerce, to the ability to have a home appliance automatically register and monitor itself over an electrical power line facility.



The overall strategy to is ensure a growing presence in the overall telecommunications service value chain. IP carriers are in their early stage and currently provide international long distance ("ILD") services using IP technology, including possibly "toll grade" quality voice, data and fax, unified messaging platforms, enhanced IP services, integrated telco and IP platforms (IP to SS7/C7) to 7 countries in Europe and Asia. They are able to offer toll grade quality services by utilizing its own dedicated network facilities rather than the public Internet. They currently these services over wholly owned networks or the Internet. The latter has serious quality and security problems.

There are two simplistic deliverables that one may expect out of an architecture. They are used for sanity checks. They are:

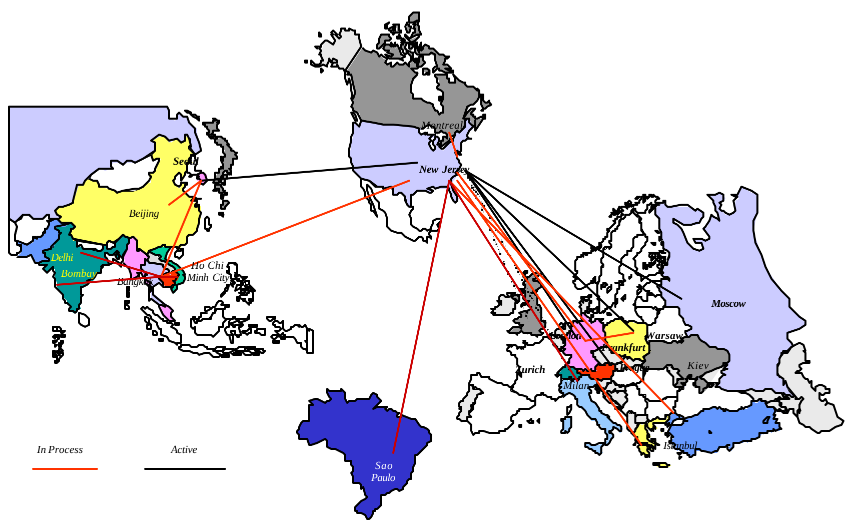
Simulator: The existence of a pull down list simulator that allows interfaces and elements. How would one create a simple model for testing the loading, performance and design optimization for an integrated IP and Telecom network. There are many tools available for each separately, but there are few for them together, if any. There is an issue on interfaces, there is an issue on consistency, and there is an issue on in band and out of band signalling.

Policy: The existence of well defined definitions to be employed in a policy development effort. The most important part of any policy is the set of definitions.

2. GLOBAL NETWORKS

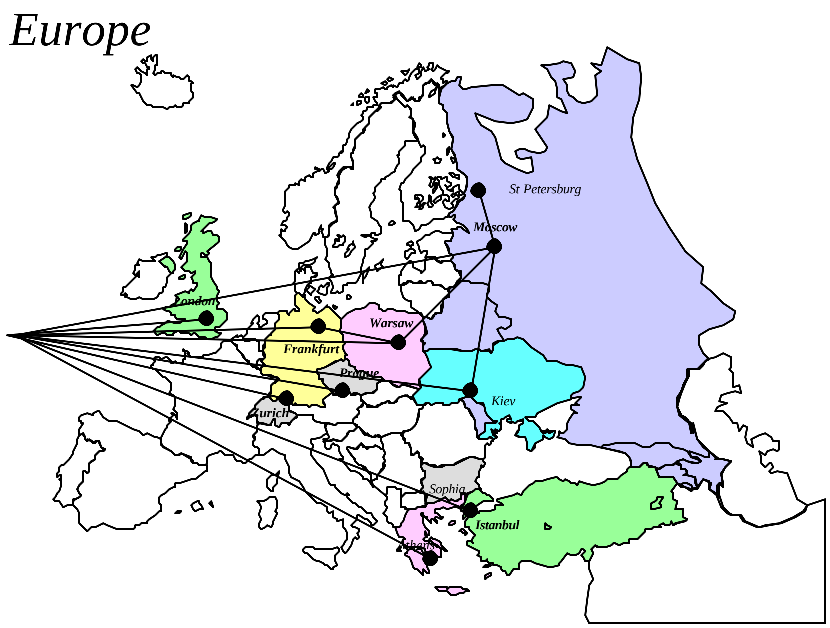
The development of a state of the art global IP network that allows it first to exploit the existing large arbitrage opportunity with international settlements and then leverage the network services through the offering of multimedia services. The following Figure depicts a typical international network.

International Network



The development of the Internet IP technology has provided a dramatically different set of alternatives for the provision of international telecommunications services. The effectiveness of the IP networks is a result of three factors: First, the network is a packet network that uses network resources only when these resources are required and not all of the time. Second, speech compression allows for the transmission of voice in a highly compressed form while retaining the quality that the consumer demands. Third, technology allows for the simple integration of the normal telephone network with multimedia communications. The network universality and low cost, the speech quality and ease of implementation, and the system deployed establishes a basis for a new and innovative market, namely international IP services.

Many companies are constructing a state of the art global IP network that allow it first to exploit the existing large arbitrage opportunity with international settlements and then leverage the network services through the offering of multimedia services. To help achieve these goals, companies have first targeted countries where deregulation of telecommunications has occurred or is pending, to introduce its service.



Many companies have developed an extensive network within in its various countries. The country network is essential for the integration and distribution of IP services and is the backbone of the IP Network.

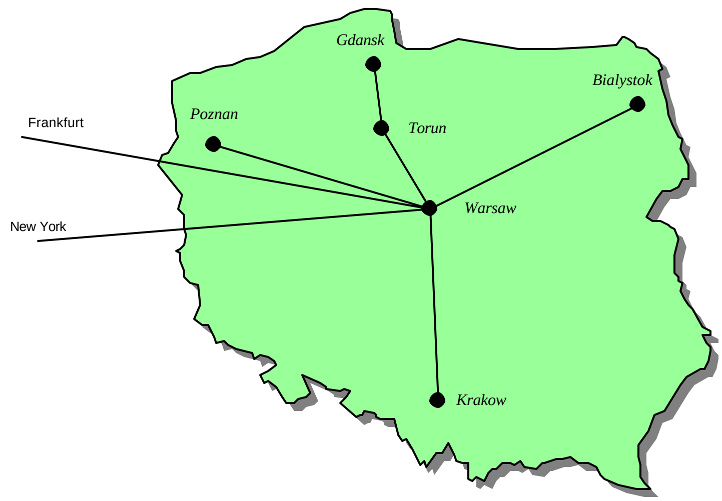
For example, one company has developed the following relationships and operational networks:

- International Access: The company has access directly from the U.S. via an IRC and via another IRC to local in country circuits. This insures redundancy and excess capacity for growth.

- Domestic Inter Exchange Carriage: The company uses local in country data networks for distribution and integration of services.

- Local Distribution: The Company has local interconnection agreements with Local Exchange Carriers as well as with several CATV companies.

Local Network

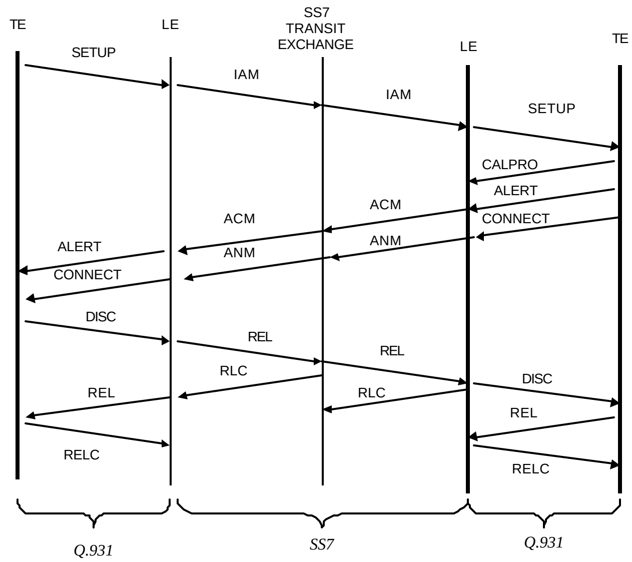


3. IP VERSUS TELCO

This section provides an overview of the world of IP and Telco and their differences. In addition it describes why they may ultimately be incompatible unless certain changes are made. The Telco world views timing as everything, calls are set up and taken down on timing. In the packet world, "every packet is an adventure" and timing is relegated to some irrelevant fact. Thus end to end is a problem.

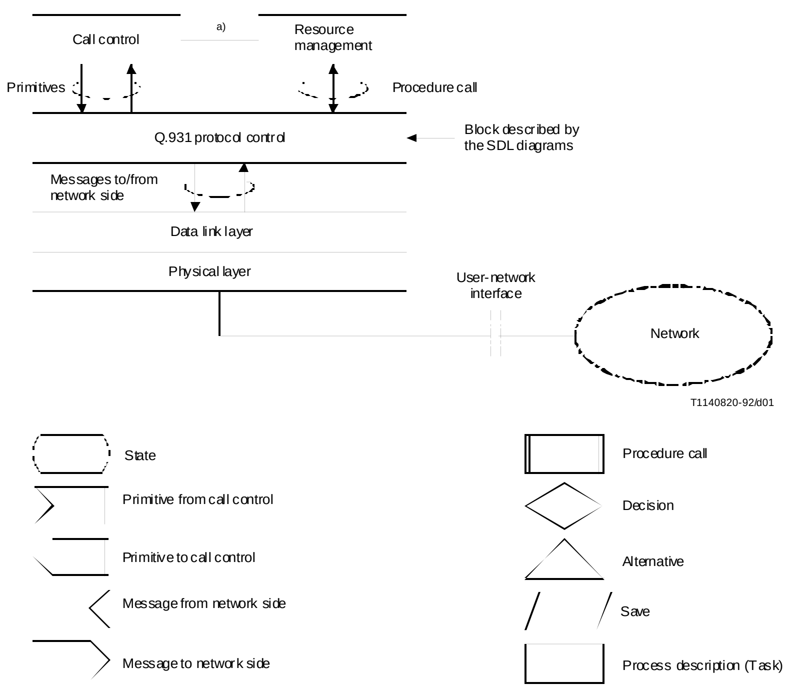
3.1 Telco Timing

In the Telco world the key to the development and deployment of the system in Telecom is the issue of timing. Timing in Telcos is where we focus our efforts as shown below. The Figure below shows call set up procedures for ISDN and SS7 networks. The issue is then the timing on the signalling that is shown from one point to another.



The above Figure clearly depicts the way in which the Telco world views networks. The issue of layers may also play a part but timing is a more important issue.

The methodology used in the Telco world is the use of SDL diagrams for simulation. This approach is shown below for the Q.931 protocols. The SDL approach is used extensively in the telecom environment to create unite, elements, and interfaces.

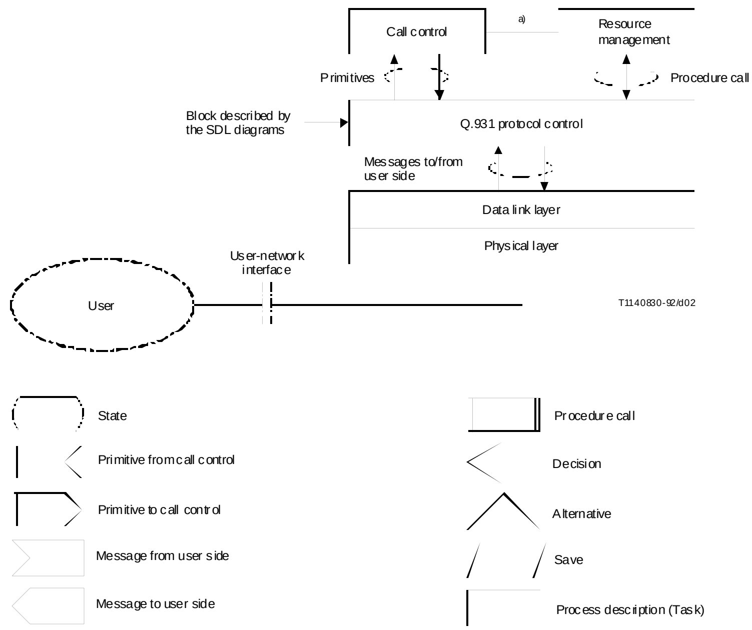


[a] Not described in the SDL diagrams.

FIGURE A.1/Q.931 (Sheet 1 of 2)

Key to Q.931 protocol control SDL diagrams (user side)

The following is the detail for the non-user side. Note that the elements are defined as they were in the user side but now address the issues of the network side. The user and the network issues again relate to timing and less to layers.



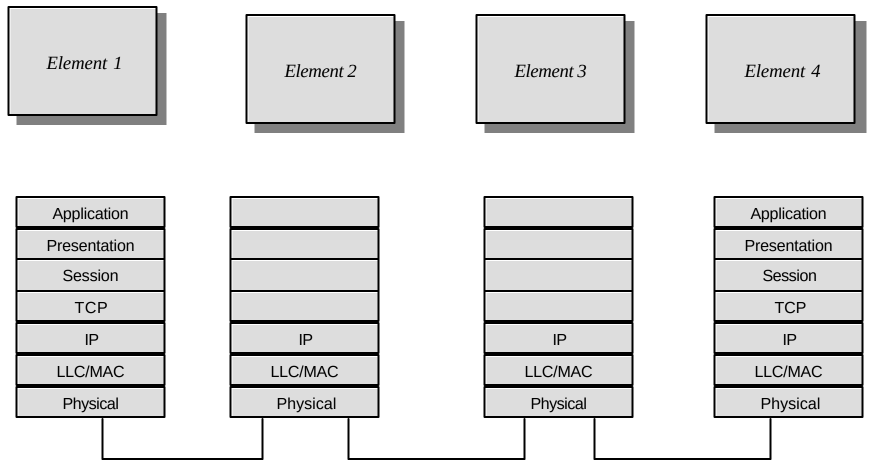
a) Not described in the SDL diagrams.

FIGURE A.1/Q.931 (Sheet 2 of 2)

Key to protocol control SDL diagrams (network side)

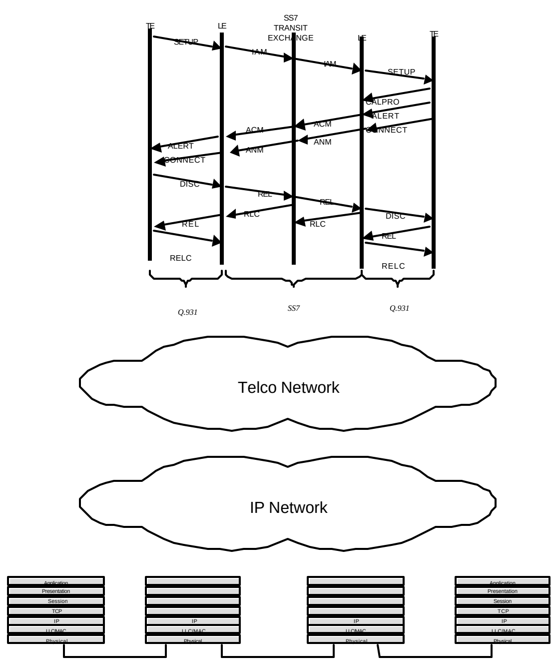
3.2 IP Layering

The IP works on layers more than timing. The typical IP link is shown below. Here we have shown the issue of the seven layer OSI architecture that we all to frequently talk about.

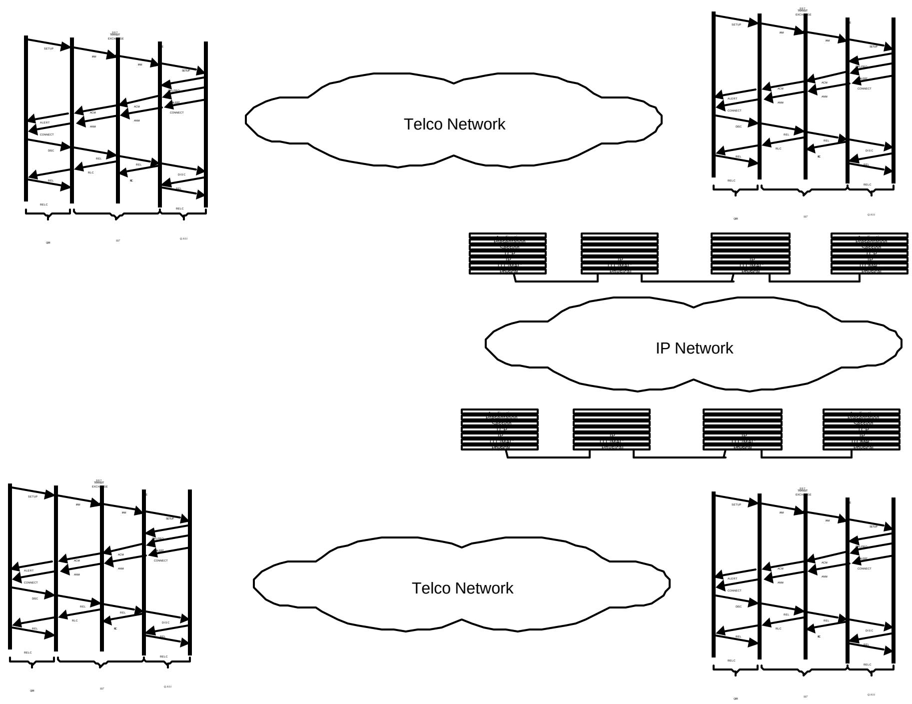


3.3 Integration

No we can combine these in an integrated fashion. The following Figure shows how we have timing in Telco and layers in IP.



The following Figure depicts the issue as to how these worlds may exist together. Namly the issue of timing to layer to timing. The current IP world does not permit the effective use of this architecture. In the following Figure we depict the issue of connecting between a Telco regime to an IP regime and then to a Telco regime. The "problem" is that we need to maintain the timing integrity of the Telco regime across the boundary of a layered but not time IP regime.



4. ENTRY TO ARCHITECTURE

We can now start with the basics of Architecture, which we latter define as a combination of Elements, Interfaces and a World View. The Elements are the Grammar, the Interfaces the Syntax, and the World View the overall language structure. There is a need to "talk" between the two worlds, namely IP and Telco.

Architecture = Elements + Interfaces + World View

For IP this equals:

$$Architecture_{IPWorld} = Elements_{IPWorld} + Interfaces_{IPWorld}[Layered\_Communications] + World\_View[Distributed]$$

For Telco this equals:

$$Architecture_{TelcoWorld} = Elements_{TelcoWorld} + Interfaces_{TelcoWorld}[Time-Based\_Communications] + World\_View[Hierarchical]$$

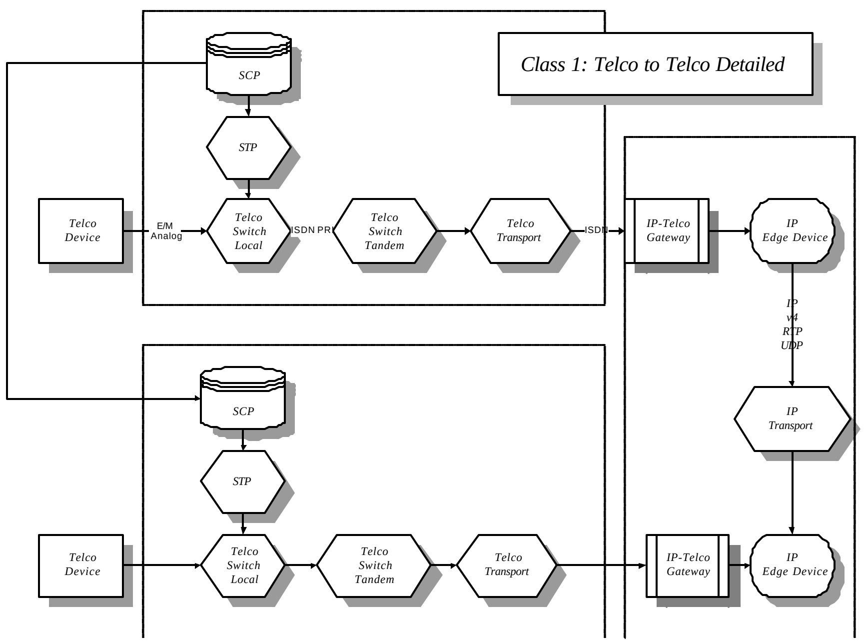
The elements may be different but the key difference is in the interfaces; layered versus time based differences.

The concept of a telecommunications architecture has been a cornerstone in the development of new telecommunications systems. However, the structural elements of these architectures have not played a role in the development of policies. In this section we will develop the concept of an architecture as a means to understand the network as both a market and regulatory entity, and will provide a new set of perspectives for viewing the network in terms of a new paradigms and world views.

4.1 Architecture Definition

In order to adequately understand the technical, operational, economic, and policy issues of IP Telephony, or many of the other issues related to the Internet, it is useful to have an architecture. Much of the early work of the Internet used the OSI several layer architecture, albeit much of the work was along lines in which the elements of that architecture were refuted. However everyone had a vocabulary and set of examples to frame the discussion and to develop alternatives. TCP/IP was often framed in contradistinction to the OSI architecture. It gave a franca lingua for the development of ideas and new systems and services. This report provides an architecture to frame the discussion of IP Telephony, albeit an initial architecture which may be improved and evolved to meet the increased integration of telephony with Internet type communications systems and services.

An architecture, first, requires that the underlying system be treated in terms of a set of commonly understood elements and that these elements have a clearly demarcated set of functions and interfaces that allow for the combining of the basic set of elements.[2] The way the elements then can be combined, reflected against the ultimate types of services provided, determine the architecture. Take for example the following embodiment of an IP Telephony system.



It is critical to understand the two words that are key to the above discussion; elements and interfaces. Elements may be physical or logical in nature and they may be at the same or different "levels" in the architecture. A physical element is a telephone, a logical element is the IP protocol common in the internet. The interface is the way elements talk to one another, at the same or between different levels.

An ***architecture***, secondly, is driven by two factors; technology and world view.

Technology places bounds on what is achievable, however those bounds are typically well beyond the limits that are self-imposed by the designer or architect in their view of the user in their world. This concept

[2] Kuhn, Scientific Revolutions, and McGarty, Harvard University, November, 1990.

of architecture and the use of design elements is critical in understanding the paradigms used in the structure of information systems.

World view is the more powerful driver in architecture. It is necessary to develop one further concept before it is possible to define the World View element.

To understand the importance of an architecture it is necessary for the introduction of the concept of ***paradigms***. In the most simple sense the ***Paradigm*** is the typical example or simple and well understood example that we all relate to when we speak of the new concepts. It is the hierarchy of the classic telephone network and it is the "hourglass" minimalism of the Internet. The paradigms are opposing in these cases.

The concept of a paradigm is in essence the collection of current technologies and ways we use them that we have at hand for the network and the ways we put these elements together. New paradigms result from new technologies. New technologies allow for the placing of the elements together in new ways. Furthermore, it is possible to demonstrate that the world view, that is how we view ourselves and our environment is based upon the our acceptance of these paradigms, as either collections of techniques and technologies or as collections of embodiments of these techniques and technologies in "examples".

4.2 World View

The concept of a ***world view*** is an overlying concept that goes to the heart of the arguments made in this paper. To better understand what it implies, we further examine several common views and analyze the implications of each. If we view our world as hierarchical, then the network may very well reflect that view. If we further add to that view a bias towards voice communications, these two element will be reflected in all that we do. The very observations that we make about our environment and the needs of the users will be reflected against that view. As an external observer, we at best can deconstruct the view and using the abilities of the hermeneutic observer, determine the intent of the builder of the networks.

World View is the way an individual, entity, organization views the world and their relationship to that world and how that world and this relationship will evolve over some period of time.

Take, for example, the classic telecommunications network versus the Internet. The world view of the classic network is one of hierarchical management and control, of a centralized force, of an economic system of pervasive scale economies, large factories needing large amounts of throughput to effect low costs, and thus the need for a monopoly. In contrast the Internet view, developed from the mind set of the 60's and 70's is a break with that classic world view, it states that embodiment of power to smaller entities as good, that power and intelligence can be distributed, shared, and effectively utilized in an open communal mode, and that furthermore with the introduction of Moore's law and the like, "silicon is free", and the need for colossal monopolies is no longer necessary and in fact counter productive to innovation. Understanding this the definition of architecture evolves.

Architecture can be defined as the conceptual embodiment of a world view, using the commonly understood set of constructural elements, based upon the available set of technologies. ***Architecture is the combination and embodiment of three elements; the common elements, the underlying technology and the world view.***

The above elements of world view and architecture is developed for the IP Telephony concept.

5. ELEMENTS

Elements are the building blocks of any architecture. They are the commonly understood abstractions of paradigms that we use in defining our system and in describing our architecture. Any element may never actually exist and the embodiment of it may have functionality that differ from the definition. However, the definition is critical to the establishment of a common set of terms and a language to communicate to others about the embodiments.

5.1 IP Elements

The architectural elements for IP Telephony are defined as follows:

Element	*Function*	*Examples*
Telco End User Device	Provides for the interface between the end user and the overall service offering and using signalling generally acceptable to the telecommunications world. This would be ISDN, E/M Wink, R2, and other forms of signalling.	Normal telephone hand set. Wireless or mobile handset.
IP End User Device	Provides for the interface between the end user and the overall service offering and using signalling generally acceptable to the IP world.	PC Computer Other Computer IP Based Mobile set. Palm Computer Generalized IP appliance.
Telco Transport	This is the Telco Transport network which may be an amalgam of TDM, clear channel (V.35), ATM, Frame Relay, or even sub IP networks, which interconnect to Telco Edge Devices and which have no Telco-IP Gateway in between. It should be noted that the Telco may choose to convert somewhere in between to IP but that conversion may appear as a seamless and transparent transport vehicle.	PSTN Shared Networks Closed User Networks.
IP Transport	This is a classic IP network which at Layer 3 is all IP. What appears below this is also an amalgam of various transport mechanisms.	Internet Intranets Private Networks Closed Networks
Telco-IP Gateway	This elements is a device which allows for the interconnection and interfacing in a relatively seamless fashion with the Telco and IP networks. It interfaces on one side with the Telco Edge Device and on the other side with the IP Edge Device. It converts Telco signalling to IP signalling and the reverse.	IP Gateways (see Motorola, Lucent, Cisco, et al)
Telco Edge Device	The Telco Edge Device is generally a switch or switch like elements. It can perform interconnection, it can do billing, provisioning, network management, and it may very well also be able to interface to the SS7/C7 global fabric. The Telco Edge Device is a complex set of sub elements that allow for the Telco End User Device to communicate across the Telco Transport network and to inter-communicate with any and all other Telco users via a Telco End User Device.	Switch, Class 5 or 4 ATM Switch Frame Relay System
IP Edge Device	The IP Edge Device provides for the interconnection to an IP transport network. It generally is a router but may be extended into a broader base of devices. It handles the IP protocol interface as well as the TCP interface if such is necessary for the connection. It also provides	Router IP Switch

Element	*Function*	*Examples*
	for the edge point control signalling that may be required for Quality of Service requirements.	
Hub	This is a general point of interconnectivity allowing high speed interfaces from and to other locations. A Hub interconnects with Sub Hubs and Nodes. Generally there is one per main region.	Cisco Router Connection IP Switch DACS
Sub Hub	A Regional concentration point of interconnection interfacing with Hubs and Nodes.	Cisco Router Connection IP Switch DACS
Node	A local terminating point.	Edge devices and End Devices

The elements must have a sense of completeness and a lack of ambiguity. In addition these elements must be embodiable, namely they must be attainable by using existing or developable technology.

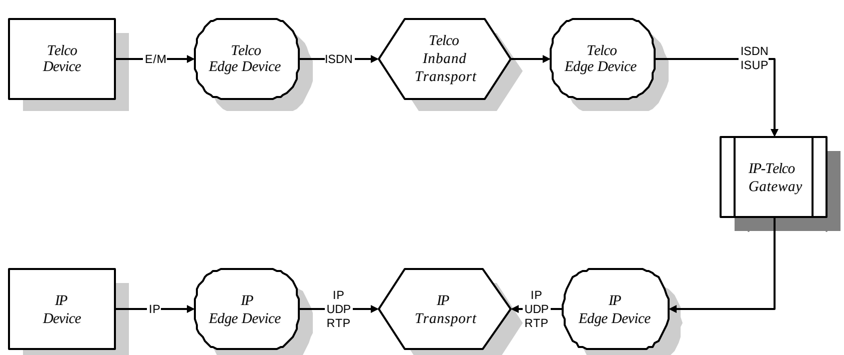
5.2 Element Interconnection

The interconnection of the elements is done through the process of interfaces as will be discussed in the next section. However, the Interconection of embodied systems to connect the elements must also be done. Elements must have specifications, and the specifications must state what their input and output interfaces look and act like. It must specify how the devices can be interconnected to achieve a system.

6. INTERFACES

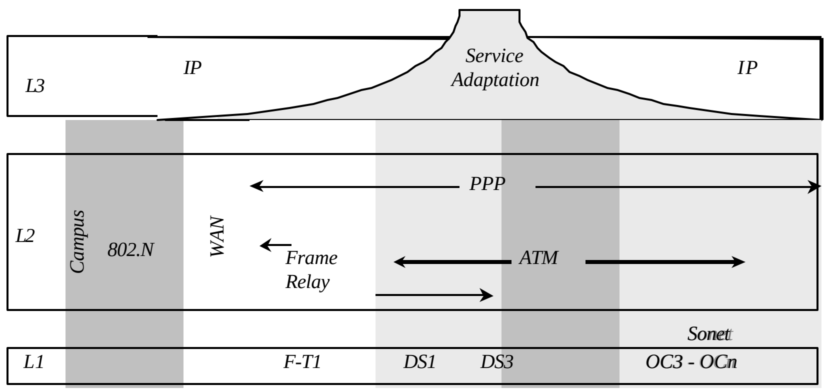
Interfaces are the statement of how Elements interconnect. The Interface may be defined at many levels, physical, logical, and even in a regulatory manner. For example ISDN, PRI, using ITU Q.931 is a typical interface between elements as defined for IP Telephony. These concepts are shown in the following Figure.

Elements and Edge Devices



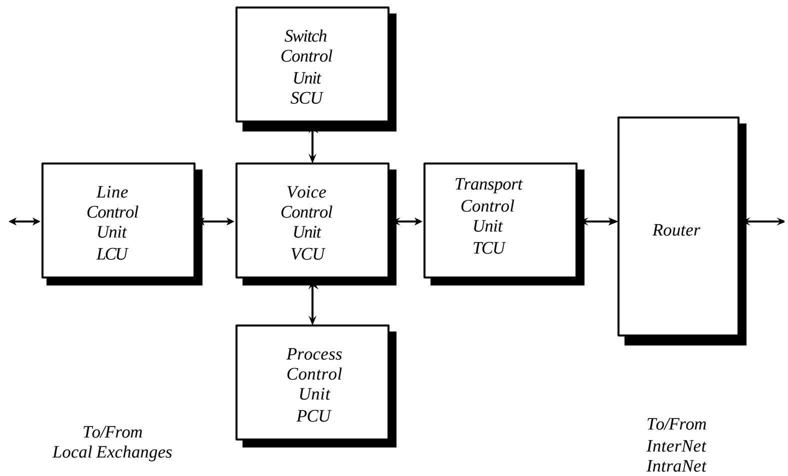
Interfaces are a very critical factor in the overall architecture. They will be used to ensure the issue of openness, interconnection and access. As this Report has stated earlier, the Internet, IP, and it embodiments are predicated on an open architecture. That architecture requires common and well understood elements but moreover it requires common, stable, and well accepted interfaces.

The following Figure shows an adaptation of how Layer 1, 2, and 3, the IP layer, interact and interface. ATM and Frame Relay are not IP, as may have been apt to think. Interfaces are how we connect both horizontally and vertically. Vertical interfaces are the interconnection between the Layers, horizontal is the interconnection between the same Layer. However, there is iso-connection or iso-connectivity and there is alius-connection or alius-connectivity. Iso connectivity is horizontal or vertical connectivity between two common communications environments, that is one generally not requiring a gateway functionality, namely no conversion, just communications. Alius connectivity, “different” connectivity, is between two different communication media and generally requires a conversion device called a gateway. This IP is iso, Telco to Telco is iso, but Telco to IP is alius connectivity.



6.1 *IP End User Element*

IP Telephony has several network elements. The key element is the IP Voice Gateway or Node, IVN, which generally interconnects the telecommunications service to the IP network and also the opposite function. The IVN network elements that we generically introduced above can be further described as follows; switches, transport, interface and control. We describe the options and architectural alternatives to these in the following. We assume that there is a device called the IVN, or IP voice node. The basic system building block is the IP Voice Node (IVN), shown below:



LCU: The Line Control Unit, LCU, is the interface between the telephone network and the IVN. The LCU provides for call initiation and termination. The initial LCU provides for signaling to and from the local telephone network. This unit must provide for SS7 and C7 interfacing or PRI or similar interfacing. One approach may be to front end the LCU with a PBX or switch which may perform these functions.

PCU: Process Control Unit, PCU, provides the capability of controlling the processes of a general nature such as network management, billing, and the IVN provisioning capability. The PCU has an SNMP agent for network management and a billing control unit, BCU, for the management of calling cards and other similar elements.

SCU: The SCU, or switch control unit, provides for the conversion between the telephone number for dialing and the TCP/IP address for Intranet connectivity. On initiation, the IVN sends the SCU the telephone number to be called. The SCU converts the telephone number into an IP address and the SCU inserts this in the transmitted packet. On receive or termination the SCU converts the IP address and other header information into the terminating called number. The SCU sends this to the LCU, which then connects this to the local exchange.

VCU: This is the Voice Processor or the voice card. It compresses or decompresses the speech, turns it into a packet, and sequences, schedules, and protocol converts it for Intranet access.

TCU: The Transport Control Unit, TCU, provides for the packet synchronization between transmit and receive. It is the scheduler of the packets on transmit and the synchronizer of the packets on receive. It also provides for the sorting out of the packets on transmit and receive. The TCU interfaces with the Router via an Ethernet interface.

Router: This is a standard router.

Using this IVN element, IP can be used to provide end to end telecommunications services. The IVN allows for the conversion of voice to packets, the signalling and address conversion to route the calls, and the supervision and control to provide billing and network management. The IVN is then placed in one of two generic configurations as shown below.

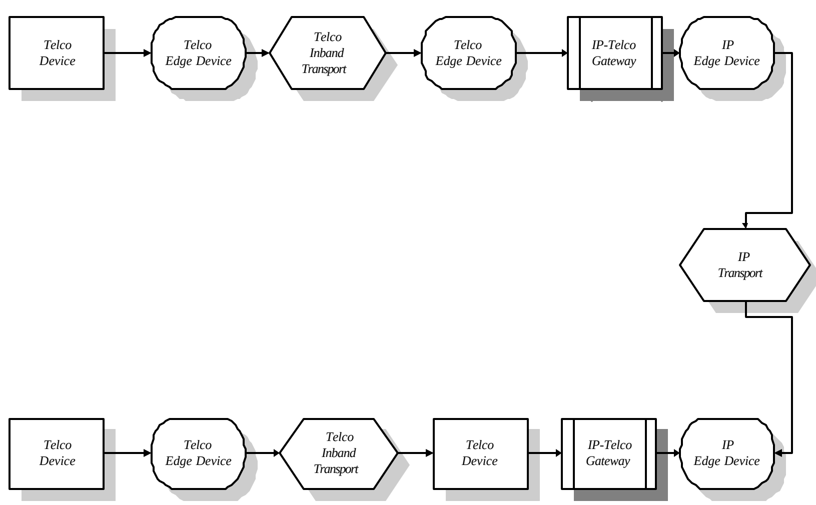
6.2 Architectural Alternatives

The following Table summarizes several Classes of Architectural alternatives.[3] This list is not exhaustive and is merely the first set of simplifications offered by Clark. It joins the issue of iso and alius interconnection. It does so through the gateway elements that we have defined.

Class	Description	Characteristic
Class 1	The end-users employ existing telephony equipment, and the Internet is used for a portion of the connection through interconnects with the PSTN (e.g., IP used over long-distance segments).	TEL - PSTN - IP - PSTN - TEL
Class 2	POTS telephone devices are interconnected with computer telephony devices.	TEL - PSTN - IP - COMP
Class 3	Computer telephony devices are used at both ends and the connection is made solely through the Internet.	COMP - IP - COMP
Class 4	An arbitrary set of POTS and public and private IP network links. The example to the right illustrates the use of the PSTN to provide a connection between two Internet "subclouds"	COMP - IP - PSTN - IP - COMP

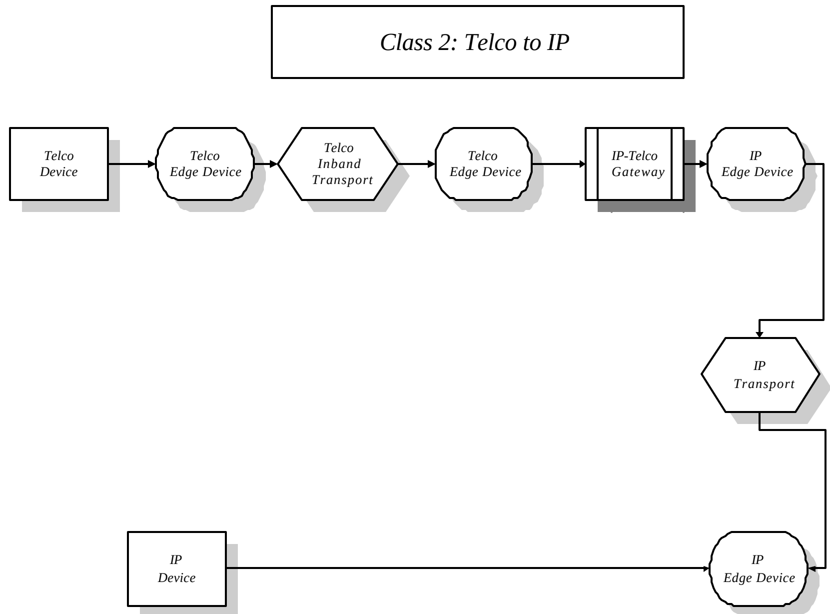
A Class 1 Network is shown below. It includes all of the elements that have been defined above. It should be noted that the issue of SS7/C7 is embedded in the Telco Edge Devices and the Telco Transport elements. SS7 is handled over that link. Whether it is further handled over the IP section is open to debate.

Class 1: Telco to Telco

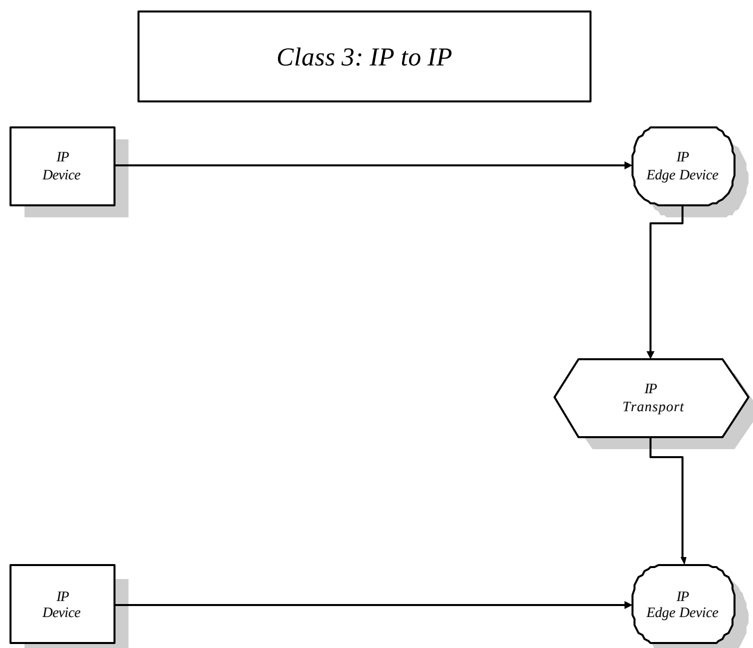


A Class 2 Network is shown below. In this case there is Telco on one side and IP on the other. In this case there is the first introduction of an IP end device which may be a computer but may also be any IP enable device which can perform the telephony function. Thus this architecture Class admits the introduction of pure IP telephone and then presents the concept of IP Dial Tone as the interface between the IP Edge Device and the IP End User Device.

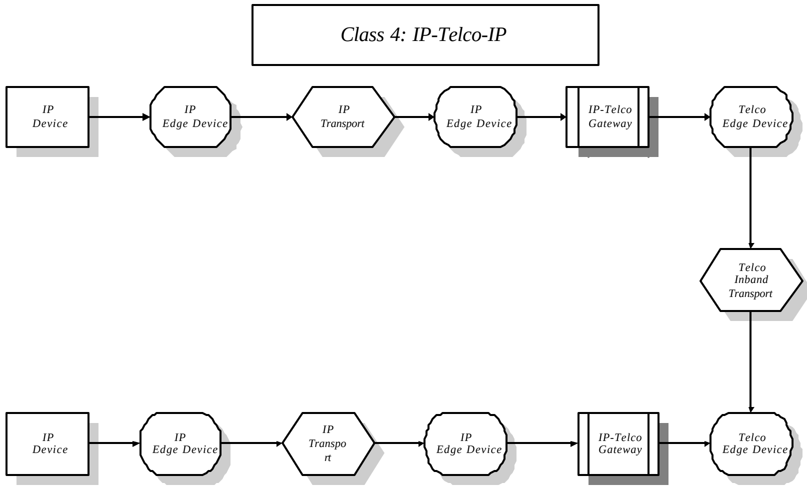
[3] End-user equipment: telephone (TEL) or computer (COMP), equipment in the middle: IP network (IP), PSTN network (PSTN): SOURCE Adapted (with extensions) from David D. Clark. 1997. *A Taxonomy of Internet Telephony Applications*. Proceedings of the Telecommunications Policy Research Conference (TPRC).



A Class 3 Network is shown below. This is a pure IP environment and it embodies all of the elements that were presented on the IP side of the Class 2 Architecture. What is missing in this design is any connection to the Telephone network. This may present a clear and present problem if the needs of the regulatory world impose demands upon the IP world that can only be handled by the interconnection, at least for signalling and certain sets of special services.



A Class 4 Network is shown below. The problems of Class 3 disappear and the network ha IP to IP but the Telco fabric is embedded in the center of the network.



7. STANDARD TELEPHONY VS IP TELECOMMUNICATIONS

The PSTN has evolved from a basic circuit-switching feature capability and services to advanced intelligent networks with centralized, closed application databases and service creation environments. More recently, it has evolved to even greater separation of the applications from the "operating system" and the underlying infrastructure and to a more open service creation environment. Hybrid services, which combine the PSTN and the Internet content and attributes, such as Internet Call Waiting, are emerging.

The PSTN is evolving to a more-data centric architecture with high-speed data access, transport, and switching. The transport backbone is evolving with greater deployment of optical transport, such as wave division multiplexing, to accommodate the voracious bandwidth demand. The greater deployment of ATM serves as a basis for higher layer data networking functions, such as IP, and applications which require different qualities-of-service with voice, perhaps, serving as the most stringent. It is recognized that the evolution of IP over ATM over WDM or IP directly over WDM is emerging with the elimination of SONET or SDH per se as some of the capabilities are designed into the optical or photonics layer. ATM serves not only to multiplex multimedia cells but also is used to emulate circuits.

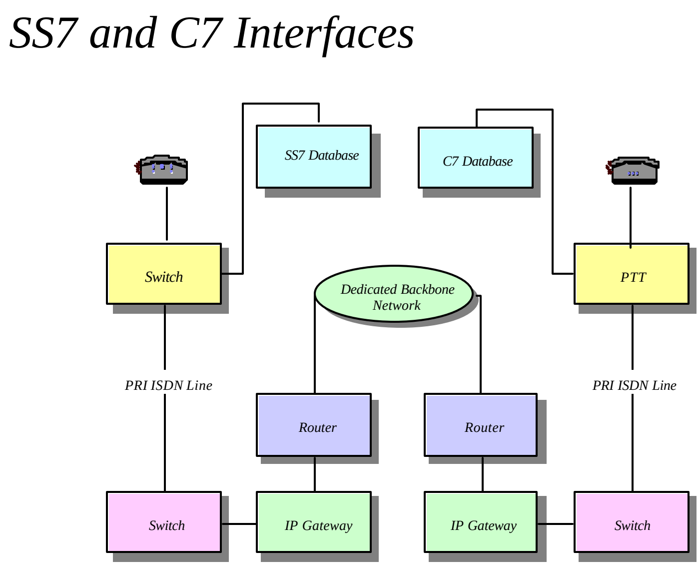
The following Table presents a set of features that are inherent in a Telco based network and compares this to the IP world.

Feature	IP Telephony	Standard Telephony
911	None	Required by state and federal laws. Is enabled in all Telco systems. For CLECs they may generally obtain access for a fee vial ILEC.
CALEA	Possible with FCC	Required of all CLECs, ILECs, IECs, and other carriers as well as CMRS carriers and other open group wireless carriers.
Number Portability	None unless via Telco SS7 database.	Required by law and now operational available as part of FCC unbundling requirement.
SS7/C7	Only via Telco element	Generally available domestically and generally required for any and all international traffic. Allows for effective traffic balancing and loading and dramatically reduces call set up and call management.
Service Level Agreements	None	Generally all carriers on a peering, refiling, or transit basis.

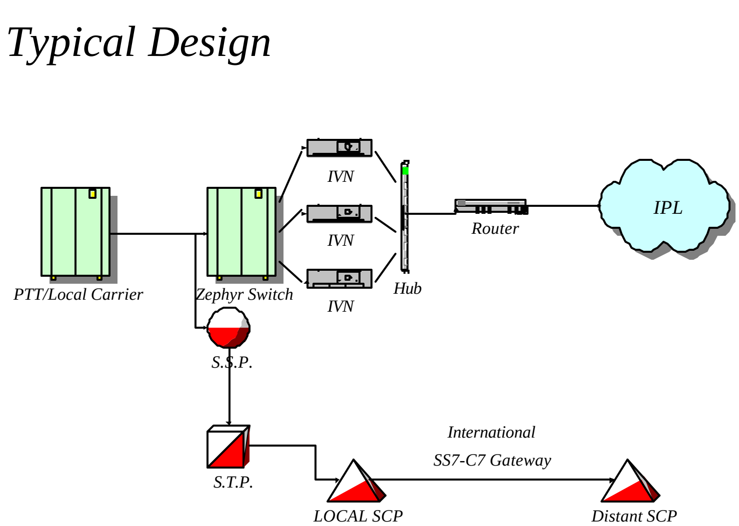
Feature	IP Telephony	Standard Telephony
Peering	Limited	Generally between carriers of a similar class.
Interconnection	Limited, generally via Telco networks	Laws and regulations, especially in TA96 for the interconnection of systems and services.
Access	Limited	As with interconnection but in the broader context of access.
Transit	Limited	This is the transit of traffic which is not originated or terminated. This is currently a common practice amongst peering carriers and in certain arbitrage relationships.
Unbundling	None	Required by regulation this is the separate sale and support of unbundled network elements.
Operator Services	None	If there is a customer question or service request there is a Operator Services, Dial "O", available in most countries. This is both an artifact from the days of manual switching but in many countries it has been regulatory mandated to ensure end user access in the event of system failures.
Directory Assistance	None	There is a regulatory mandate for Directory Assistance to obtain telephone numbers.
Service Level Reporting	None	In almost all regulatory domains, State PUCs and other entities require the Telco based carrier to file Service Level Reports which details certain levels of service performance. These are public and made a matter of public record as well as a measurement of the performance of the carrier. In many cases remedies at the Administrative Law level are available if the service levels fall below some defined acceptable threshold.
Dialing Plans	None	Dialing plans are set up and controlled by quasi regulatory bodies.
Network Management	Limited	The networks are managed in a complex fashion to ensure integrity and reliability. In contrast to IP services where there is no network management.
Billing	Limited	Billing is generally a standardized methodology with standardized data formats. Billing and the fees, taxes, tariffs are a matter of public record in most cases and remedies are available via the Administrative process.
Enhanced Services Platforms	Open via IP	The networks allow for the development and deployment of enhanced services platforms.
Local and LD Partitioning	None	Generally a regulatory distinction in US and elsewhere as to local and long distance services. US is not atypical. Poland, Thailand, Korea, Japan, and most other countries, under WTO, have separate entities in each area, and have separate regulatory control over each separately.

7.1 Telco Interconnection

The interconnection between the Telco environment and the IP environment is further shown in the following Figure. Here we depict the issue of SS7 connectivity, an out of band signaling system that has a set of shared, but common, databases, the SCPs, which are at the heart of many of the features and services inherent in the day to day operations of a Telco network, such as 800 services, number portability, and the actualization of Homer and Roamer registries.

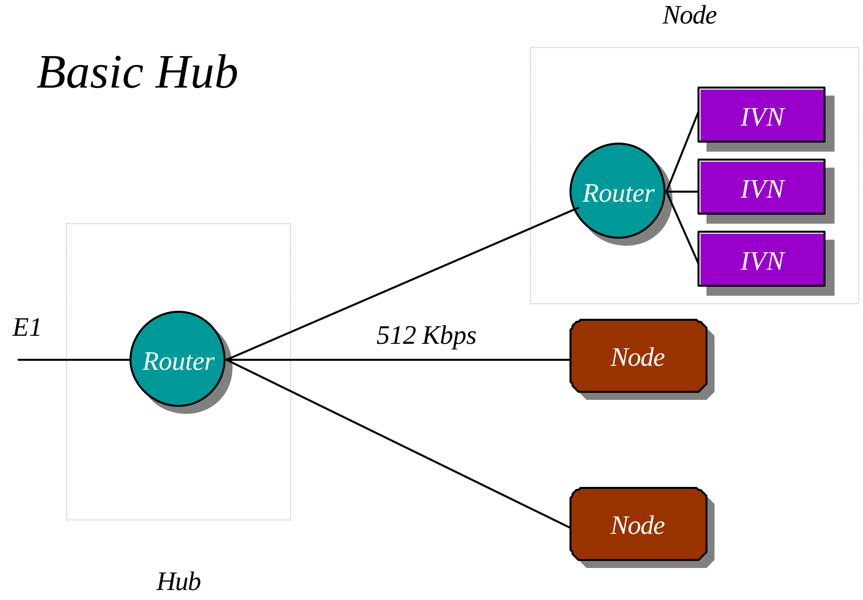


The actual embodiment of the SS7 network across international domains is depicted below. The issue here depicted is that there are really two separate and distance signaling regimes, the IP regime of in band signaling via Level 3 and 4 and above, and the Telco world signaling which is out of band and is at the control of well established international standards.

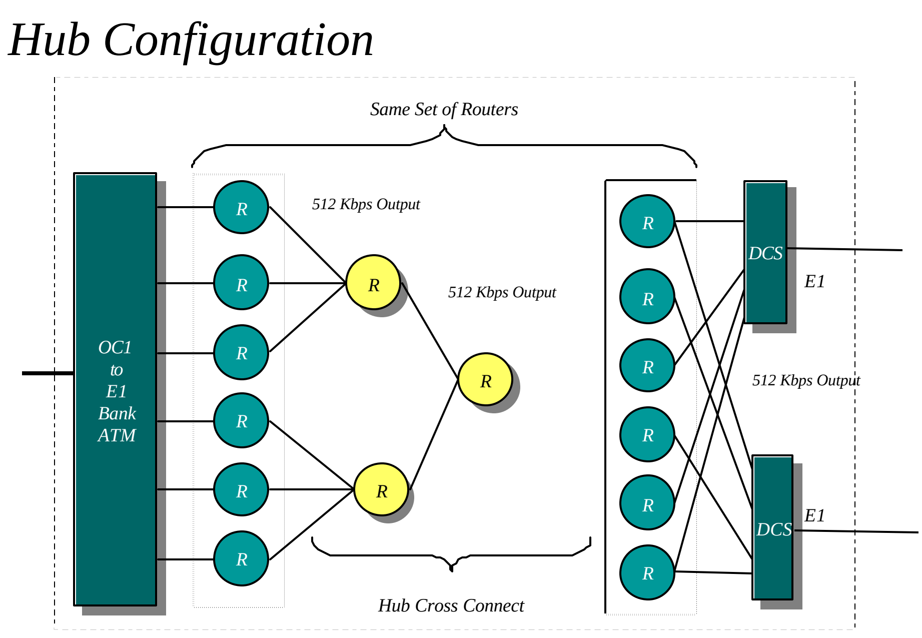


7.2 Global Network Elements

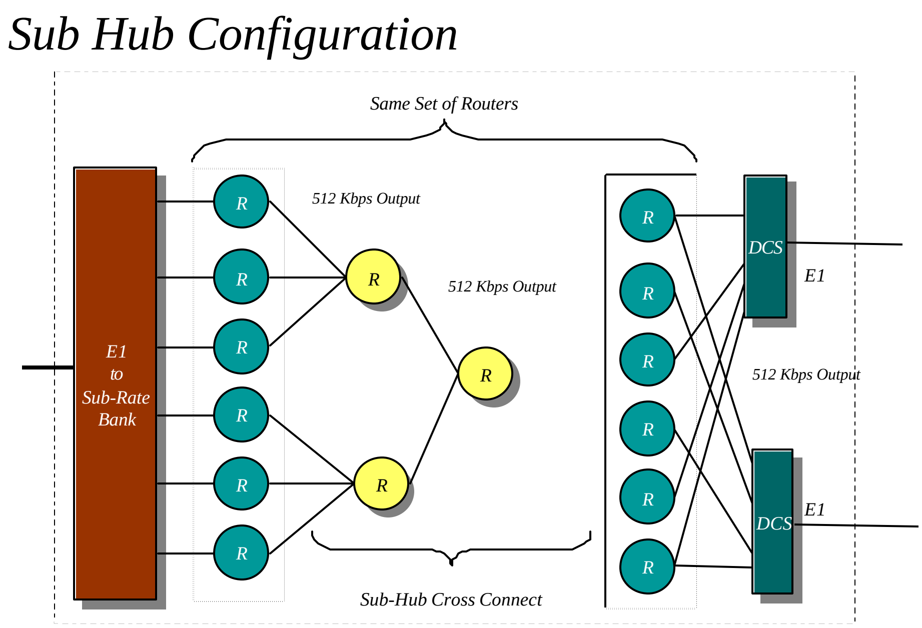
The three global IP elements are the hub, the sub-hub and the node. The basic hub is merely a set of elements that allow the IP network transport to be interfaced with end user devices.



The complete hub is shown below. It must interface with any type of high speed backbone network, and then must be able to interconnect sub-hubs or nodes to any other. The embodiment below is one of many. It uses small process Cisco routers such as the 4000 series and since this series has limited processor capacity, namely packets per second, "pps", it must "fan" out to ensure that multiple routers allow for full connectivity. A simple way around this is to use a 12000 series router to attain full high speed multi Mpps capability. However, the typical approach is to build the network slowly and the result is the concatenation of routers, which is a common element of Internet design. The problem resulting from this concatenation is poor load management and poor responsiveness, as we shall show latter.

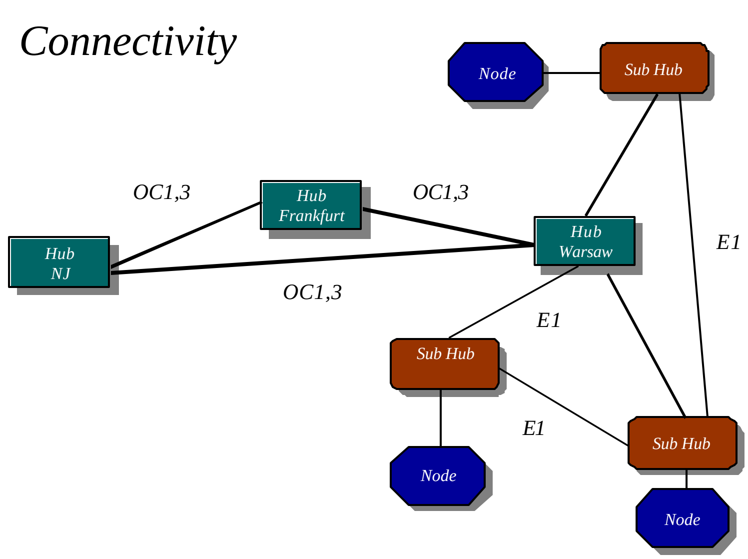


The sub-hub is shown below. It allows for local interconnection and in many ways is an optimizer between local low speed networks and high speed backbone networks. It is an elements in an overall least cost routing system.



7.3 IP and Telco Connectivity

The full network connectivity is shown below. This network shows a high speed dedicated backbone connecting Hubs, which connect to sub-hubs and then to local nodes. The main issue is how best to load balance telco traffic with other forms of non-time sensitive traffic.



7.4 Capacity and Loading

The following is a brief analysis of the issues associated with loading of a router in a voice telecommunications environment. Similar analyses may be performed as we integrate a full multimedia capability. The analysis is composed of the following:

Codec Capability: We assume that the codec handles a CELP or CELP like processor and does an average of 8:1 compression.

Headers: The headers are TCP/IP and that the use of a header compression is a reduction to a level of 40 bits overhead reduced from the 320 normally in a TCP/IP packet.

Voice Sample Stuffing: The assumption is that there are a minimum of 2 and a maximum of 3 sample per packet. The samples are 20 msec samples. The 3 sample leads to a minimum of 60 msec delay and the issue is one of what delay is acceptable over a clear channel.

Header Compression: The header compression assumes RFC 2507 or similar compatibility. The RFC 2507 standards assumes that headers are sent once and then only changes are sent on all other transmissions unless the header information changes. Using 2507 the router then rather than processing each header just does a table look up after receipt of the packet. The router processor load is now theoretically reduced.

Router Capacity; The 4500 Cisco router is a 100 MHz processor and also allegedly has the ability to handle 55,000 packets per second uncompressed. However, it has been alleged that with header compression in the Cisco router the packet capacity is reduced to 11,000. This is unbelievable especially give the RFC 2507 implementation.

7.4.1 Case 1: No Header, 3 Samples per packet

The following analysis is of the Loading of a Cisco 4500 router based upon a CELP codec and using an 8:1 compression and full loading. Clearly the Router sees 5,000 packets per sec. The 4500 router is a 100 MHz processor and has the capacity to handle this load. There is no header compression.

No Header Compression Using Standard RTP UDP and TCP/IP Processing with 8:1 CELP Codec

Samples per Sec	*8,000*
Bits per sample	*8*
Compression Ratio	*8*
Length of CELP Sequence (msec)	*20*
Effective Date Rate	*8,000*
Effective bits per CELP Sample	*160*
No Samples per Packet	*3*
No Bits per packet	*480*
TCP Overhead (Bits/packet)	*160*
IP Overhead (bits/packet)	*160*
Total Bits per Packet	*800*
Packet Efficiency	*60%*
Packets per sec per voice channel	*17*
Bits per packet	*800*
Data rate per voice Channel	*13,333*

Maximum No Voice channels per IVN	*30*
MaxNo Packets per sec per IVN	*500*
Max No IVN per Router	*10*
Max No Packets per sec per Router	*5,000*

7.4.2 Case 2: No Header, 1 Sample per packet

The following is for one sample per packet. Note the efficiency goes down to 33% which is totally unacceptable.

No Header Compression Using Standard RTP UDP and TCP/IP Processing with 8:1 CELP Codec

Samples per Sec	*8,000*
Bits per sample	*8*
Compression Ratio	*8*
Length of CELP Sequence (msec)	*20*
Effective Date Rate	*8,000*
Effective bits per CELP Sample	*160*
No Samples per Packet	*1*
No Bits per packet	*160*
TCP Overhead (Bits/packet)	*160*
IP Overhead (bits/packet)	*160*
Total Bits per Packet	*480*
Packet Efficiency	*33%*
Packets per sec per voice channel	*50*
Bits per packet	*480*
Data rate per voice Channel	*24,000*

Maximum No Voice channels per IVN	*30*
MaxNo Packets per sec per IVN	*1,500*
Max No IVN per Router	*10*
Max No Packets per sec per Router	*15,000*

7.4.3 Case 3: Header Compression, 1 Sample per packet

Using header compression, RFC 2507, and as shown as compliant with Cisco 4500 routers, the packet load goes up but the processing required under 2507 is much simpler since it looks at only 40 bit header and not the 320 bit header. There is a 82.75% reduction in processor load for this header compression algorithm. Thus the 4500 should be able to handle up to 40,000 packets per second, and if the 4500 is 55,000 packets per second, and not the 5,000 with full TCP/IP load. The reason is the issue of the 2507 having the look up table approach which simplifies the process speed problem.

Header Compression (RFC 2507 & Cisco Rel 11.2(5)F Overhead for IPUDP/RTP

Samples per Sec	*8,000*
Bits per sample	*8*
Compression Ratio	*8*
Length of CELP Sequence (msec)	*20*
Effective Date Rate	*8,000*
Effective bits per CELP Sample	*160*
No Samples per Packet	*1*
No Bits per packet	*160*
TCP Overhead (Bits/packet)	*12*
IP Overhead (bits/packet)	*28*
Total Bits per Packet	*200*
Packet Efficiency	*80%*
Packets per sec per voice channel	*50*
Bits per packet	*200*
Data rate per voice Channel	*10,000*

Maximum No Voice channels per IVN	*30*
MaxNo Packets per sec per IVN	*1,500*
Max No IVN per Router	*10*
Max No Packets per sec per Router	*15,000*

7.4.4 Case 4: Header Compression, 3 Samples per packet

The following is the analysis for the use of three samples per packet.

Header Compression (RFC 2507 & Cisco Rel 11.2(5)F Overhead for IPUDP/RTP

Samples per Sec	*8,000*
Bits per sample	*8*
Compression Ratio	*8*
Length of CELP Sequence (msec)	*20*
Effective Date Rate	*8,000*
Effective bits per CELP Sample	*160*
No Samples per Packet	*3*
No Bits per packet	*480*
TCP Overhead (Bits/packet)	*12*
IP Overhead (bits/packet)	*28*
Total Bits per Packet	*520*
Packet Efficiency	*92%*
Packets per sec per voice channel	*17*
Bits per packet	*520*
Data rate per voice Channel	*8,667*

Maximum No Voice channels per IVN	*30*
MaxNo Packets per sec per IVN	*500*
Max No IVN per Router	*10*
Max No Packets per sec per Router	*5,000*

7.5 Operations Support Systems

Operations Support Systems are key elements in the delivery of a quality level of service. They are integral to the telecommunications environment and are partially present in the IP world. Ironically the SNMP capabilities of IP are key to the delivery of a fully integrated OSS support fabric. However, in contrast, the TMN environment of the Telco world is poorly constructed. The Telco OSS fabric is a patch quilt of separate elements, whereas the OSS fabric of IP is an integral set of functions facilitated by SNMP. This issue is what are the OSS elements and how best are they integrated, and where do they fit into the architecture.

The following is a summary of the OSS elements. The provision of OSS will entail several dimensions of service capabilities. These may or may not be from a single service providers but must be able to be integrated into a single service provisioning element.

Network Management

The local and national backbone network must be managed and controlled in a real time fashion. Operating entities, at all levels of operation, must have the capability of being monitored as to operational effectiveness, network performance, and impact on their interconnecting network elements. The Network Manager must be able to determine the locations of any and all outages or system degradation points in the network, or in any other network that a customer may have access to.

IEC Interface Management

IEC Management must be performed to ensure the establishment and proper maintenance of any and all IEC interfaces and connections to the local WLL network. The overall management service will include such items as circuit ordering and scheduling, circuit interface negotiations, optimization of network design, and the physical management of the integration of the networks. It has been assumed that the IEC interfaces will be consistent with all other equal access provisions and that no IEC will receive any preferential treatment.

Customer Service

The Customer Service function will provide customer service capabilities supporting such areas as billing, service quality, inquiries, service features, service upgrades, and complaints. Customer Service is the most important part of the provision of service. The customer only needs Customer Service when the service is not totally transparent and thus when the service is not meeting the customers needs. Therefore, Customer Service is the MOST critical function that can be provided and must be provided with utmost care and effectiveness.

Billing

The Billing Function must be responsible for the full life cycle factors associate with billing. This includes the capture of billing data, both local and IEC, the processing of the data, the preparation of the bill, the issuance of the bill, and the collection, reporting of and corrections to the bill. The billing function in essence consists of all functions necessary to collect the bill for services rendered, commencing from the time the service is requested, through the necessary intermediates steps and through all intermediaries.

Telemarketing

The Telemarketing function is required to support the sales function. The sales function is a three separate process. Step one is the use of advertising to stimulate market demand and activate the customer response. The Telemarketing step, the second step, requires the inbound reception of purchase requests. The third step is the completion of the sale by the delivery by direct sales or express delivery of the portable to the customers.

Repair Dispatching and Maintenance

The RD&M function is required when a fault is detected. The function prepares the trouble ticket and the dispatch ticket and the inventory dispatch ticket. It closes out all repairs and reports on the results.

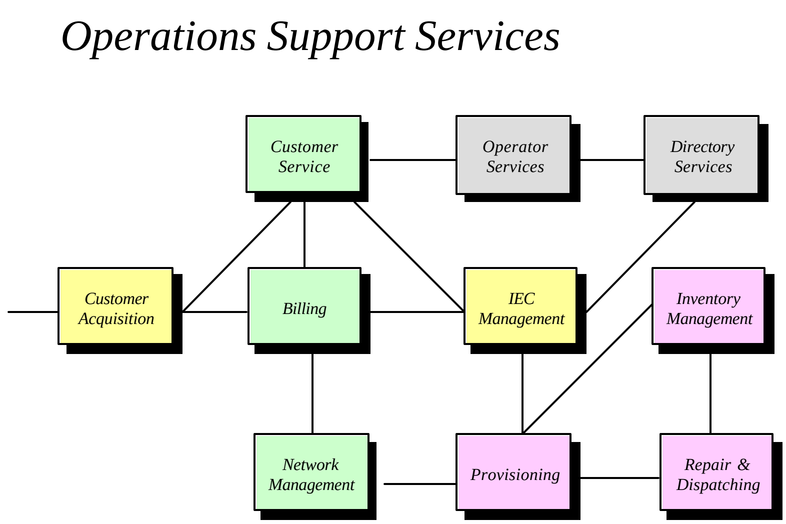
Inventory Management (MRO/MRP)

The Inventory Management function, also providing Materials Resource Planning (MRP) and Material Resource Ordering (MRO) functions, will be responsible for the ordering and inventorying of all system and network elements needed for growth, spares, and maintenance. The function must be fully integrated and electronically supported ensuring the minimum response time and cost for inventory carrying. As a goal, the Manager seeks to have a "Just in Time" system that ensures the availability of the parts needed without the need for any stockpiling of equipment. This not only applies to the network elements but to the portables sent to the customers as well.

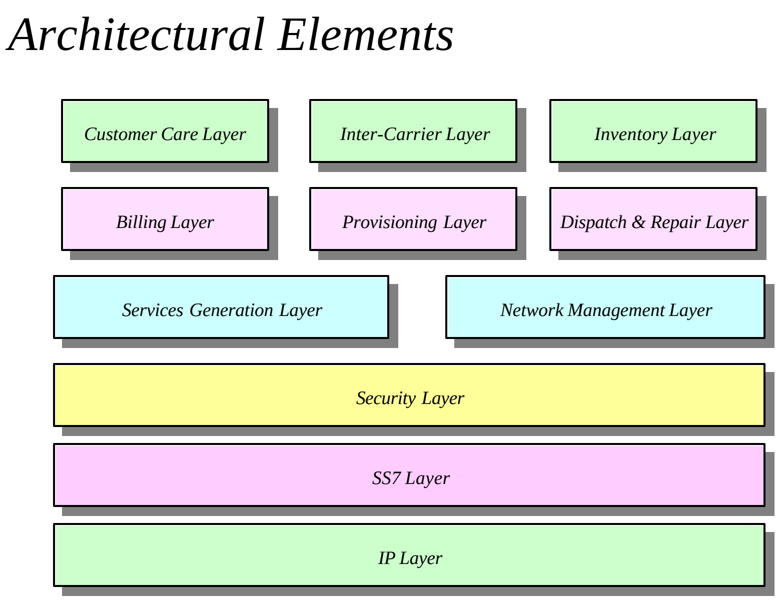
Operator Services and Directory Assistance

The Operator Services and Directory System intended to support access to all WLL customers. This system must allow any individual in any location to obtain ready access to any WLL subscriber. The objective is to ensure that all calls are equally inbound and outbound.

The following Figure depicts the relationship of the various OSS elements.



The relationship of the OSS architecture to the IP and Telco is shown below. There are several ways in which this can be envisioned. The approach of the TMN world is to have the layers aligned in accord with the OSI layers. However, the OSS systems are integrated into may of the layers in a non one-to-one manner. For example, billing may be at layers 3, 4, 5, and 7. How does one implement this on a layered approach? This is a yet to be determined problem.



8. CONCLUSIONS

This paper has been an attempt to address the issues regarding IP telecommunications systems. It has defined a set of elements and interfaces and has shown that these elements can be used for the embodiment of actual classes of IP telecommunications systems. However this paper in a real sense raises more questions than it answers. Namely;

1. Are the elements and the interfaces a complete set.

2. Are the elements and interface embodiable in a real system.

3. Is the architecture a reflection of a “world view” that actualizes the confluence in telecommunications and IP.

4. Is the architecture one that is transformable and sustainable as technology is improved and changes or is it merely a reflection of the technology as currently understood.

5. Does the use of the architecture allow system designers to obtain new insights into systems and specify new system elements as may be reflected in new technology choices.

6. Is the architecture extensible. Can the architecture create the concept of “IP Dial Tone” as articulated in the initial sections of the paper.

We believe that the development of an architecture with elements and interfaces is essential. It is a common ground for communications and it allows system designers to understand where the edge of the envelope is in the embodiment of systems and services.

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