ELSEVIER

Computer Networks 31 (1999) 157–168

COMPUTER NETWORKS

Telephony in the year 2005

Joseph Rinde *

MCI, 2100 Reston Pkwy, Reston, VA 20191-1218, USA

Abstract

The growth of packet-based voice services is leading to integration of voice and other services over packet switched data networks. This paper explores a possible path that the telephone service industry may follow as this integration is accelerated by technological advances that improve the capabilities of packet-based services while reducing their costs. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: IP telephony; Internet

1. Introduction

We live in a time of rapid technological change, especially in the field of telecommunications. The term Internet years, a take off on dog years, attempts to capture the speed with which we experience the evolution of new products and services. To attempt in this environment to predict the telecommunications scene seven years hence is a daunting undertaking. Surely whatever we predict today will be only a vague perception of the reality to come. No matter how extravagant the prediction, it will pale in comparison with the reality that will be.

With this in mind we can take the trends of today and extrapolate them in a skyward direction, secure that if we are wrong it is likely to be on the conservative side.

One of the hottest topics in telecommunications today is the use of packet data networks, and the Internet in particular, to transport voice and fax, traffic that classically runs on the circuit switched Public Switched Telephone Network (PSTN). All of this started three years ago when VocalTec introduced a PC application that enabled voice communications between multimedia PCs across the Internet. That first example of affordable *phone calls* over the Internet was a hobbyist tool. Soon a plethora of vendors offered improved approaches to voice communications between PCs, and more importantly between PCs and phones, and between phones using the Internet as the long distance transport (see Fig. 1).

The rest of this paper projects future developments by looking at the history of telephony from the vantagepoint of the year 2005.

2. Early history

The earliest history of Internet telephony was plagued with poor voice quality and substantial delays. These drawbacks were overcome by the allure

* Corresponding author. Tel.: +1-703-715-7163; fax: +1-703-715-7252; e-mail: joe_rinde@mci.net

1389-1286/99/$ - see front matter
PII: S0169-7552(98)00266-9

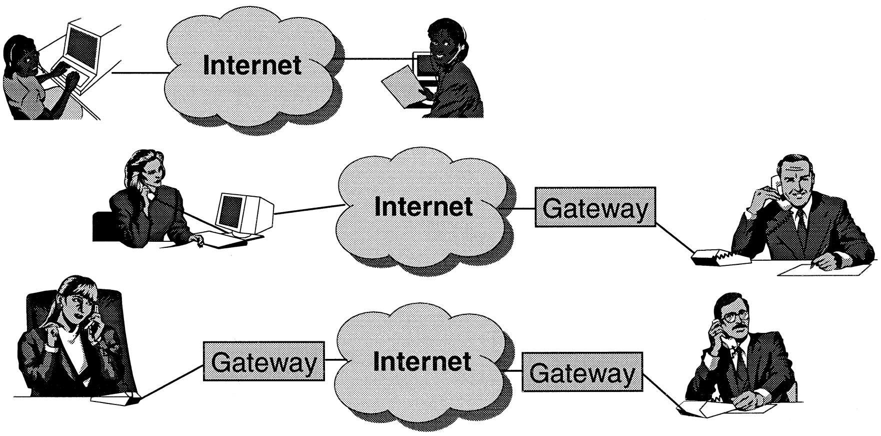

Fig. 1. Communications across the Internet between PCs, PC and phone, and between phones.

of *free phone calls over the Internet*. Of course the calls were not free, but they were inexpensive compared to PSTN charges. In the case of international calls prices were as low as 25% of discounted PSTN rates. The commercialization of this cost disparity led to an array of services that arbitraged the cost of Internet telephony against the artificially high prices of regulated international PSTN services. The service quality could be lower than the PSTN (round trip delays sometimes as high as 3 seconds) and still attract customers willing to trade quality for a lower price.

Many questioned the ability of the Internet to deliver voice quality on a par with the PSTN. Delay was the big issue, for within two years of the inception of this technology, codecs were introduced that produced voice quality comparable to the Pulse Code Modulation (PCM) form of digitization used in the PSTN, at a fraction of the standard 64 kbps full duplex transmission used in the PSTN [1].

The first use of voice over IP was made with PCs at each end. The PCs introduced delay from a number of sources. The primary source was the sound card. Early sound cards were half-duplex and were designed to play sound sources from CD-ROMs. Given the multi-second delay in loading the software and getting data off early CD-ROM drives, sound card designers saw no need to optimize the additional delay they introduced, which was typically less than a second. However, delays of a half-second in the sound card alone equaled the round trip delay in satellite telephony. Additional delay came from the 486 Intel processors in the PCs used in those early years. Not only was the processor comparatively slow, but the predominant operating system (Windows 3.1) was not a true multi-tasking system, which introduced delays as it emulated multi-tasking. The early uses were frequently made with dial access to the Internet. Even using the newest modems of that time (28.8 kbps) noticeable serialization delay was introduced at each end of the connection.

In addition to the end point delays the *best effort* nature of the Internet introduced variable delays and even gaps in the transmission of voice that resulted in a perceptibly lower Quality of Service (QoS) than on the PSTN.

Delay was sometimes tolerable in two party conversations, but in multi-party conference calls delay was very disruptive as multiple parties vied to speak next. Delay in this environment resulted in unintended interruptions and an awkward back-off process to resolve who would continue speaking. Even in two party conversations, delay was more readily accepted by price conscious consumers than by business users.

3. From 1998 to 2001

Although there were some early applications of Internet telephony in 1996 and 1997, it was not until

1998 that services based on this new technology became significant.

The continued explosive growth of data capacity during this period took bandwidth used for data from one tenth that used for the PSTN to full parity. This growth included the public Internet, and corporate intranets of various technologies (IP, Frame Relay, ATM, etc.). Some of this growth was fueled by the migration of voice from the PSTN to data networks.

This period saw the evolution of carrier grade (high reliability and scalable) services based on IP carriage of voice. Not only did the delay problem get resolved but also a whole new set of services came into being. Carrier grade equipment made it economical to build large systems to accommodate the expanding customer base. This equipment also provided the high reliability needed for a mass telecommunications service.

No longer was IP telephony only *a cheaper way to make calls*, but a *better way* to make them. The implementation of the World Trade Organization (WTO) [2] agreement to bring competition into international telecommunications brought Internet telephony and PSTN prices to a cost basis, and on an equal regulatory footing. With price parity on the regulatory front IP telephony took advantage of the lower costs of transmission (lower switching costs, and reduced bandwidth usage) to offer a competitive service for normal telephony. IP telephony additionally offered services not available on the PSTN, a combination that sped the deployment of IP telephony.

3.1. Fax

The PSTN was also used to transmit documents using fax machines. These machines turned scanned documents into data for transmission over the circuit switched PSTN. Early offerings in this field enabled the transmission of fax over the Internet. The earliest offerings did not integrate voice and fax support, rather concentrating on vertical applications of transmitting traditional PSTN traffic over IP.

Transmission of fax over the Internet introduced a different, though no less demanding set of design challenges. In the voice arena delay was king, while packet loss, if not too high, was tolerable. Lost packets represented a 30 to 90 millisecond loss of speech. The terminating Internet equipment, whether PC or gateway, typically extrapolated from the last sound received to fill the void. Human intelligence at the receiving end was usually able to make up for the missing sounds. In the worst case, too many lost packets resulted in the informal retransmission protocol ‘‘what did you say?’’

Fax on the other hand could tolerate a moderate amount of delay (the T.30 protocol used by fax machines specified how much delay was acceptable before the call failed), but it could not tolerate lost bits. Retransmitting lost packets across the Internet could insure no loss of data while various *tricks* from the T.30 protocol could be used to stall for time while the retransmission was taking place. Other complications of fax over the Internet involved modem handshaking. Some of these functions were done from the near end gateway for efficiency and for timing necessities, while other functions were allowed to happen between the end fax machine modems.

3.2. So what was better about IP telephony?

The earliest useful IP telephony was phone to phone service. Although the number of PC users continued to grow they still represented a small percentage of the population, compared to the number of telephone handset users. With phone to phone services customers continued to use their existing telephone handsets, calling local access points to enter the IP telephony system. After dialing the local access number the caller entered his billing number followed by the destination telephone number. This was reminiscent of the multi-stage dialing of the competitive long distance carrier offerings before equal access.

In 1984 the United States required the local telephone companies to offer equal access, allowing customers to pre-select which carrier would carry their long distance calls. This allowed customers of all long distance carriers to dial calls the same way, without the need for additional digits. This made it possible for carriers other than AT&T to offer equally convenient services. Before equal access competitors were restricted to offering multi-stage dialing which limited their ability to penetrate the market. As an example when equal access started in 1984 MCI, after 20 years of effort, had only 4% of the US domestic long distance market. By 1998, after 14 years of equal access, MCI had 20% of the market.

The delay problem was solved in several ways. For phone to phone service gateways with dedicated DSP chips minimized the processing delay. High-speed connections to backbone transport networks minimized the transmission delay. Some carriers accomplished this by building separate networks for voice traffic, carefully engineering those networks to keep queuing delays to a minimum. Other carriers implemented priority queues to allow a mixture of voice and other traffic, less demanding of real time performance. The latter allowed economies of scale to be applied on the aggregated traffic. Careful engineering of the network was required by both approaches.

Two other factors contributed to the cost-effective implementation of IP telephony in this time period. First, the cost of IP equipment came down. Ever-bigger routers at ever lower per bit costs drove the, already low, cost per switched bit down by two orders of magnitude at the beginning of this time period and another two orders of magnitude by the end of this time period. Similarly, the gateways used to interface PSTN initiated calls to the IP transport came down in price by one order of magnitude. This cost was further reduced by IP enabled handsets, that incorporated the gateway function in the customer equipment, removing that factor entirely from the carrier's cost equation when servicing such customers.

The second key factor was a reduction in bandwidth cost on international circuits. With the introduction of new optical cables with far higher capacities, and the retrofitting of some existing optical cables to increase capacity, the abundance of transoceanic bandwidth brought prices down. This made it feasible to cost effectively engineer transoceanic IP networks to provide the same level of low delay voice carriage that could be provided on continental service.

The combination of faster processors and lower priced bandwidth enabled IP telephony in this period to deliver CD quality sound between IP phones. Soon customers started complaining about the *poor* quality of voice over the PSTN.

3.3. The year 1998

At the beginning of this period true costs of voice carriage over IP and PSTN networks were very similar [3]. Where IP carriage used less bandwidth over continental routes and IP switching was a little cheaper (by less than a factor of 2) the high cost of the gateways almost eliminated the cost advantage of IP carriage. Arbitrage was the operative driver. Using Internet transport regulatory costs, such as access charges, were circumvented. In the United States this reduced the comparative *cost* of IP carriage by an additional 4 cents a minute. This was a huge advantage given that the cost of transport was less than 1.5 cents a minute. The savings on transport were almost insignificant compared to the savings on access charge avoidance. Other costs, such as sales and marketing, network operations, and customer service all overshadowed the transport cost as elements in the cost equation.

Local pickup and delivery of calls used up part of the savings from access charge avoidance. The IP long distance carrier was forced to use retail services, in the form of business lines, to provide local access. Since the IP telephony provider was receiving calls at the access gateway there was no per-minute charge for the call. (In the PSTN paradigm the caller pays for the call. Since the origin gateway *receives* calls it has no per minute charges associated with the incoming calls.) The service provider's per minute cost was the monthly cost of the business line divided by the number of minutes of actual usage. The cost of the gateway port was similarly converted to a per-minute cost by dividing the monthly depreciation by the actual number of minutes used.

The technology of routers remained one step (albeit a small step) ahead of the demands of Internet growth. The period started with ATM based subnetworks operating at OC12 (622 Mbps) speeds interconnecting routers operating at OC3 (155 Mbps) speeds providing the IP backbone. It was in 1998 that IP over SONET became a reality. Until this time routers were limited to OC3 and lower speeds. Although OC3 speeds were considered substantial in those days, the number of OC3 ports on router was limited to one or two, not enough to build a network with. During 1998 and 1999 the routers began running directly over the SONET network, first at OC12 speeds and then at OC48 (2.4 Gbps). This not only allowed the backbone to keep up with capacity demand, but also reduced overhead by removing the ATM cell based subnetwork.

In the year 2000 IP over fiber bypassed the SONET network, using IP's routing flexibility in place of the SONET dual fiber rings for reliability. This freed up otherwise unusable bandwidth in the fiber network.

3.3.1. Delay

There remained the problem of delay. In 1997 many thought that reservation protocols, such as RSVP would solve the delay problem. This proved to be partly true. Reservation protocols required the normally stateless routers to recognize and monitor data flows. Although this worked well in small-scale networks it was impractical in the Internet backbone, where routers handled thousands of flows per second.

RSVP was applied successfully in corporate networks, as will be discussed further below. RSVP was also effective in access networks, such as those operated by Internet Service Providers (ISPs). The problem, as noted above, was support of RSVP in the backbone.

Differentiated QoS in the backbone was solved using priority queuing and various approaches to treating the queues differently. Placing voice packets in the high priority queue allowed those packets to move ahead of web and other file oriented traffic. Special treatment of the high priority queue in congested conditions allowed other packets to be lost before voice or fax traffic began to suffer. This manifested itself in improved voice quality as the receiver had fewer occasions to invoke its compensation algorithms to deal with lost (or significantly delayed) packets.

At the ISP to backbone interface RSVP characteristics were converted to prioritized traffic for transport across the backbone. The reverse conversion was performed at the interface to the destination ISP for delivery to the receiving IP telephony software. In this way low delay and low packet loss was reasonably assured, but at a price.

The attraction of lower cost transport using the Internet was impacted by the cost of providing a higher QoS transport. RSVP was not free to the ISPs who had to provision additional bandwidth to allow RSVP based services without serious impact to the performance of other data flows. This higher cost was passed to the RSVP requester and incorporated in the price of Internet telephony service. Similarly there was a cost for the use of prioritized traffic in the backbone. This service also required the provision of additional bandwidth to provide acceptable service to non-prioritized traffic. This cost was also passed on to the priority service requestor and added again to the cost of providing higher quality IP telephony.

By late 1998 two tiers of IP telephony appeared in the public marketplace. A high QoS version based on priority transmission, and lower QoS for cost conscious consumers. Additional service providers targeted both the consumer and the business markets that year.

The services were all based on a two-stage dial using a local access number. This requirement to dial a local number, followed by a billing number, followed by the destination telephone number limited the market penetration of the services, as most callers did not want to be bothered with the extra dialing. A PBX could provide such services transparently to the caller by automatic call diversion in a PBX. The PBX could route the call, based its least cost routing tables to a process that prefixed the dialed digits with the local access number and the billing number. Despite this ability few telecom managers were willing to do this. The reasons for this resistance were varied, but generally were related to quality concerns of mission critical communications over new services that were not under the telecom manager's control. Sometimes this was a political consideration, especially when different departments were responsible for the data and voice services. Other times it was a purely practical consideration based on limited management tools for tracking and trouble shooting voice problems on the data network.

3.3.2. Intracorporate communications

1998 saw the first large wave of usage of IP telephony for internal corporate communications. Some of this deployment was aided by PBX vendors adding IP telephony capability to their product offering, but more often it was the independent addition of an IP telephony gateway between the PBX and the data LAN.

For well-engineered enterprise networks (meaning WAN interconnection of LANs using IP over leased lines, Frame Relay, or ATM with WAN line utilization below 50%) IP telephony was added at a low marginal cost. At less than 20 kbps, half-duplex, per voice session the impact on LAN usage was negligible, especially as LANs moved to gigabit speeds. The same applied on lightly loaded WAN connections in excess of 500 kbps. This allowed inter-office calling using the enterprise data network as the *tie line* between the PBXs (Fig. 2). The use of inter-office IP telephony was transparent as the PBX was used to automatically route calls over the enterprise data network. Based on the incremental cost of using the enterprise data network per minute costs for inter-office calls dropped below 5 cents a minute, which was lower than otherwise available PSTN services.

The cost savings came with the pain of early adoption. Bugs and performance issues attended the installation of intranet based IP telephony. Some companies solved the performance problems by introducing RSVP, while others applied directed network engineering to allow the *best effort* nature of the routers to deliver acceptable service levels. The biggest unfulfilled promise of corporate based IP telephony was in the provision of international telephone service. The high cost of international data transport (whether leased lines or data services such as Frame Relay) made *engineering of the network* an expensive proposition. Where international links in the intranet were too heavily loaded, the delays introduced limited the usefulness of IP telephony in this area.

1998 also saw the first uses of the so-called *soft PBX*. This was the first generation of the IP based PBX. Some of these products supported common wire line phones while some supported IP enabled phones. It was the latter that brought about the greatest changes (Fig. 3).

Soft PBXs could replace more expensive proprietary PBXs with equipment based on industrial PC platforms. The interface of the soft PBX to common wire line phones was done through Computer Telephony Integration (CTI) hardware that had been developed for call centers and other Interactive Voice

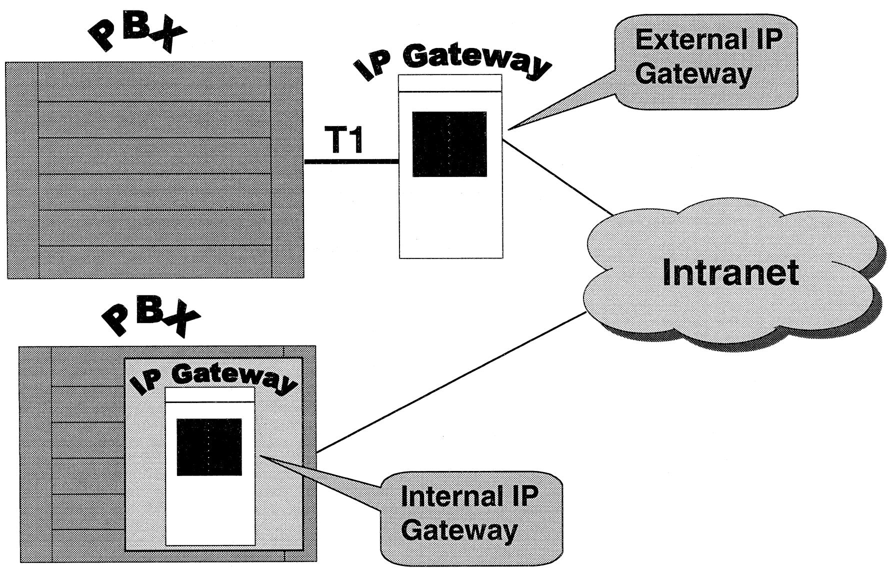

Fig. 2. Use of IP gateways to divert PBX traffic over the enterprise network.

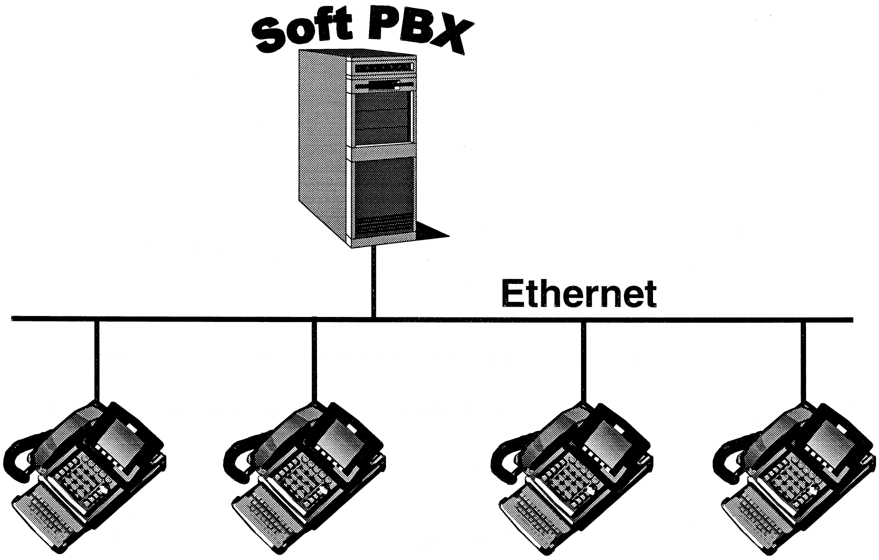

Fig. 3. Soft PBX with IP phones.

Response (IVR) applications. The wiring to the phones remained the same, but inexpensive phones could be used in place of pricey proprietary units from the traditional PBX manufacturers.

This solution suffered from the loss of *extra* function buttons and lights that were available on the proprietary phones. The attempt to compensate for this with PC support (on the assumption that every worker had a PC as well as a phone on his desk) failed to catch on. Although the PC adjunct to the phone service could provide more functionality than even the proprietary phones from classic PBXs, it required a significant change in user behavior, which slowed adoption.

The truly significant impact of the soft PBX in 1998 was the introduction of the IP enabled phone. Although the penetration of these devices was very small that year, it set the stage for a massive change to come in later years. No longer was it necessary to change user behavior when switching to a soft PBX.

The IP phone connected to the LAN, bypassing telephone wiring. This removed the CTI hardware from the soft PBX, reducing its price to the cost of the PC plus the software license. The gateway needed to connect to the PSTN was either incorporated in the soft PBX or provided by another box. The individual IP phones communicated with the soft PBX to place calls to other IP phones, or through the IP to PSTN gateway to any phone worldwide. These phones started in the US$ 300 to US$ 400 price range, which was considerably less than similarly featured phones for conventional PBXs.

The soft PBX included the usual PBX features of that time plus it provided APIs enabling new feature creation.

3.4. 1999 to 2001

These years saw significant maturation of the IP telephony technology. They also saw the relative stabilization of the market players. The traditional telecommunications companies and telecommunications equipment suppliers that adapted came to the fore along with the well-managed startups in the IP telephony industry. These events were accompanied by the arrival of lower cost transoceanic fiber capacity.

The solutions to the delay problems that were introduced in 1998 became widely deployed, and refined. By the end of this period routers were running OC192 (10 Gbps) directly over fiber, enabling the Internet backbone to support multimedia communications with acceptable delays. The new fiber capacity that became operational in 1998 started to make an impact on the prices of transoceanic bandwidth. This enabled the economic provisioning of sufficient bandwidth to support high QoS voice services on transoceanic IP networks.

3.4.1. Promises promises

From its earliest days the real promise of IP telephony was not cheaper voice but a combination of an integrated network and new compelling applications that would bring users flocking to the technology. It was in this time period that these promises started to be fulfilled in a meaningful way.

The IP enabled phone came into its own in large part as a result of new services it offered that could not be matched by conventional phones. The groundwork of infrastructure had been laid in 1998 as various forms of Digital Subscriber Line (xDSL) [4] and cable modem services were deployed to both consumers and businesses. Once high bandwidth services, at affordable prices, were available over existing wires to the premise, the entrepreneurs were able to work their magic. All of this was true in spades for commercial enterprises that had been wired with fiber.

For residential service ADSL [5] solved the issue of lifeline service (phone operation in emergencies such as power failures) by using existing phone technologies. For everyday use the high speed of ADSL provided a vehicle for IP telephony and a host of related services. ADSL allowed the use of Plain Old Telephone Service (POTS) over the same wire pair providing lifeline service. Where cable modems were used, a separate POTS line was also needed to provide lifeline service. This put cable services at a disadvantage in areas that offered ADSL services.

3.4.2. Metamorphosis in the central office

As the traffic migrated from circuit switching to packet switching the equipment in the Central Office (CO) became heavily packet oriented. Large routers with gigabit transmission made delivery of low latency data to the end user a reality. The CO became the hub of ISP activity (Fig. 4).

The nature of xDSL made it possible to provide competitive services. Any ISP could connect with a high-speed pipe, through the CO, into the user premise and offer differentiated service. The larger ISPs from the 90s entered this arena along with the competitive *local telephone companies*. The latter were predominantly large telecom companies, the classic long distance carriers and local telephone companies moving into other areas.

3.4.3. IP enabled phones

This was the era of the IP enabled phone. With increased volume the prices of these soft PBX spawned devices came down to the consumer level (under US$ 100). Common wire line phones remained cheaper but could not compete in the functionality play. With the availability of high band-

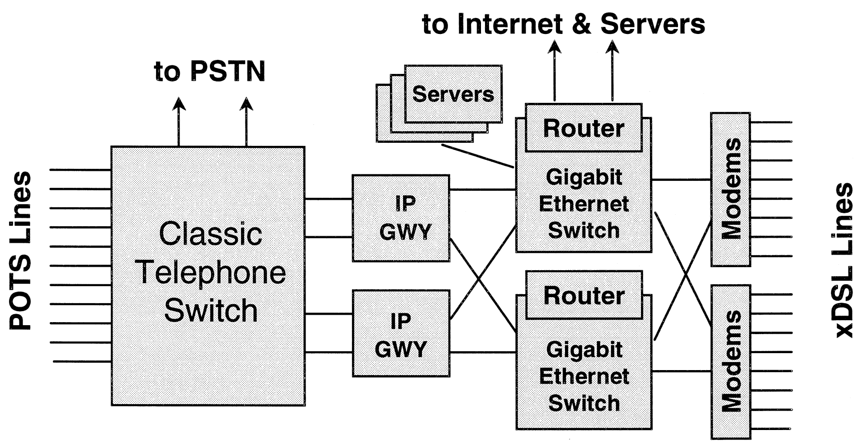

Fig. 4. The central office of the early 2000s.

width and the ever-dropping cost of computing, these devices became capable of delivering not only low delay voice, but also higher quality voice than the PSTN. Codecs to take advantage of the available bandwidth and processing power delivered CD quality voice and music. This raised the public's expectations of sound quality in telecommunications, making the conventional PSTN appear *old*.

Integration with universal mailboxes allowed home users to enjoy the same services PBX users had with message waiting lights and preprogrammed feature buttons (Fig. 5). Both home and office users enjoyed the enhanced capabilities of integrated mailboxes of voice, fax and data (e.g. e-mail) with their hand set. Although a PC or high end IP enabled phone was required to take advantage of the full capabilities of these mailboxes, most users were satisfied with simpler versions of the capabilities made available by the less expensive versions of these phones.

xDSL services brought with them LANs. This introduced LANs into many homes and also into smaller offices. These inexpensive, older technology, 100 Mbps LANs, although slow by comparison to the gigabit LANs in more sophisticated offices, opened up new options for both home and office. With the cost of the LAN included in the xDSL service additional IP enabled appliances could be installed at a low incremental cost. In the consumer space this appeared in the form of alarm system communications, health alarms for the elderly and the seriously ill, as well for the convenience-gadget oriented consumer. This facilitated the introduction of devices to monitor your weight, your consumption of vitamins (to automatically reorder), and many other every day tasks that we take for granted today.

Small offices that previously had no data infrastructure suddenly found new functionality open to them. Where limited key systems were used before; the IP enabled phone permitted Centrex and PBX like features previously only available at considerable expense. Just as the World Wide Web helped level the playing field for small companies to create a worldwide presence, so too IP enabled phones coupled with competitive service providers gave small companies the same productivity tools enjoyed by the largest of organizations.

3.4.4. How usage changed

Although video conferencing made the work place more productive it still failed to have high penetration in the residential market. Social forces kept the intrusive technology at bay in the home market.

The integrated functionality to mix voice, video and shared data with the touch of a button had a huge impact on business communications. In older times one could drop in on a colleague down the hall to collaborate, but the same did not apply to colleagues at other locations. Limited to voice communications and *out of band* data sharing (using fax, e-mail or web page) the value of collaboration across the miles was less than down the hall. With the

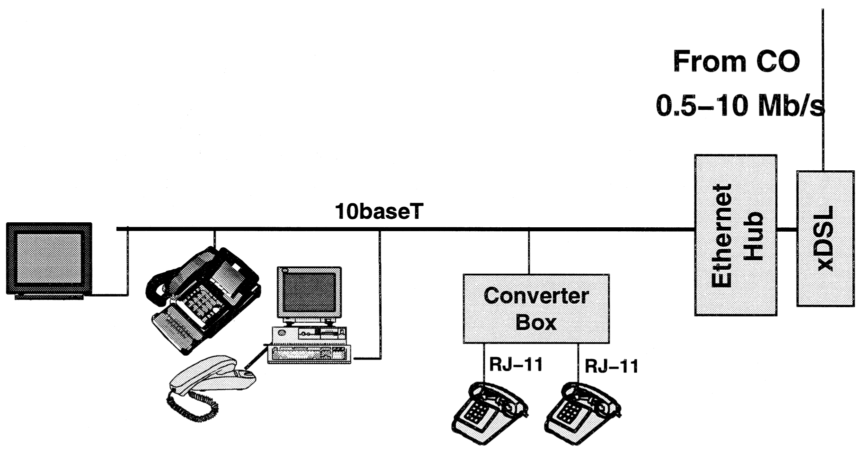

Fig. 5. Home configuration of the early 2000s.

availability of easily setup multimedia calls this changed. Now workers could knock on a colleague's virtual door across the globe just as easily as knocking on a real door (or cubicle wall) down the hall. The ensuing conversation could be carried out with shared data and visual feedback. Even more important was the ability to easily add other parties to the multimedia call. This duplicated the natural human behavior of adding others to impromptu meetings in a building when additional colleagues were needed to resolve an issue. Once these capabilities could be invoked by anyone with a PC the face of communications changed, for communications both inside and outside the company.

Connections to some parts of the world did not provide adequate voice quality, primarily due to delays. To support these locations conferencing systems included the ability to use the pre-existing PSTN capabilities to provide the voice part of the multimedia call. This use of the PSTN was done transparently by the caller's PC requesting PSTN services once the IP connection proved unable to delivery the required QoS.

3.4.5. What opened the dam

Perhaps the biggest impact on the economics of IP telephony was the drop in price of the IP enabled phones. The lower price made these devices affordable by large numbers of consumers. The most dramatic effect of this development was the reduction in the growth of gateway ports needed by IP telephony providers. Until this time calls were predominantly initiated by analogue handsets connected to the legacy PSTN. This required relatively expensive equipment to convert the PSTN style call to an IP telephony format for transmission across the IP network. At the other end another gateway was needed to reconvert the call for delivery to a PSTN connected handset.

Calls initiated or terminated by IP enabled phones did not require a gateway to connect the call to that device. Gateways were still needed to address the large installed base of analogue handsets. Indeed this installed base continues to dominate the market to this day. Nonetheless the spread of IP enabled phones slowed the growth of gateways in the IP telephony systems, providing a beneficial economic effect for service providers and customers.

Partly fueled by the growth of IP telephony the total bandwidth used for data networks grew equal to the bandwidth used by the PSTN worldwide. This set the stage for the next steps in the evolution of the telecommunications industry.

3.5. The years 2002 to 2005

By 2002 IP telephony systems' success in the developed countries led to rapid adoption of this mature technology in the developing world. Adopting countries heard their scratchy telephony services transformed into crystal clear high quality sound. Running fiber throughout urban areas brought these benefits to the city dweller. The rural population continued to build phone service using cellular technologies. Here too positive consequences from the maturation of IP telephony technology were found. These same technological developments produced higher quality sound at lower costs than were available in cellular service of the late 1990s.

The relentless march of Moore's law continued to drive down the price of IP communications, both for IP enabled phones and for PCs. Together these lower prices extended the reach of collaborative multimedia. The result was a paradox of social impact. On the one hand it brought diverse people together and on the other hand it accentuated the identity of groups.

Communities of people, whether of a nationalist, religious or racial nature, were strengthened across geographic boundaries. Not only were geographic distances removed as obstacles, but also political jurisdictions became less of a barrier. Inexpensive and intimate communications allowed extended groupings to develop stronger bonds. It was the combination of lower cost of bandwidth coupled with more efficient usage of that resource, plus the increased computing power that allowed the delivery of affordable technology for intimate communications. It was video and data sharing (in the form of photographs, videos and live events) that drove this trend. The lack of control of incoming video calls held back the video phone vision of the 1950s in the form of a phone with a picture in place of the *black phone* of yesteryear. Rather the videophone of the year 2003 was more like the camcorder of the 1990s, but in real time (allowing selective use under the control of the party being viewed). Thus many homes had one and some had many.

When using videophones, each party had the ability to turn off the video transmission at its end of the call, enabling the use of video only when required or when a close friend called. This was a socially awkward function, conveying strong signals about who the controlling party considered a close friend and conveyed even stronger signals when the status of closeness changed for the worse. This created social stresses that slowed the spread of this technology.

In a seeming paradox cheaper multimedia communications brought people of different groups together through the same intimate communications. Although this was primarily in the business environment, it spilled over into the social realm as *office parties* brought workers together with their families across geographically dispersed locations.

The continued drop of xDSL prices coupled with increased speeds expanded the types of services offered to both consumers and small businesses.

Inexpensive Internet appliances made the *smart house* affordable to millions of consumers across the world. Using an IP enabled phone a consumer could just as easily adjust his alarm system remotely as start his bathtub filling at a prescribed temperature. Bar code readers in refrigerators and pantries helped consumers keep track of inventory and locally flag the consumer to the need to reorder. For busy people the IP appliance could automatically reorder items in short supply from a nearby store.

The increased use of IP transmission resulted in faster conversion of telephone central offices to IP based services. By the end of this period a quarter of all telephone services used packet technologies. Improved battery technologies introduced in 2003 made uninterruptable power supplies (UPS) inexpensive and long lasting. This made some consumers comfortable enough to eliminate the POTS connection that was becoming a relatively larger part of the total phone bill. This reduced the pressure on circuit switched growth in the CO. This is a trend that shows no sign of abating.

It was also in this time period that the expansion of the worldwide telephone network was predominantly done by expanding the IP portion of the long distance network. The increased use of IP in the CO lowered switching costs, and improved bandwidth utilization. It also addressed the growing demand for end to end IP connectivity to facilitate the use of new functionality (such as better quality voice) across the network.

4. Conclusions

Having peered into the future of telephony we see an acceleration of the merging of circuit switched traffic (voice and fax) with packet switching technologies. Integrated services, once envisioned in the circuit switched world (remember ISDN?) will come to fruition in the packet switched world. It may be that the IP telephony of today will become the unplanned source of the ultimate integration of voice and data.

The proponents of packet switching should not beam too brightly, for the flexibility of the packet world is a two edged sword. Although *anything* is possible, given the right software and enough processing cycles, there remains the demand of backward compatibility. People want to be able to pick up any *phone* type device and call any other *phone* without worrying about what kind of hardware of software is at either end or in the middle. This is the challenge that the industry must meet to make a reality of the future described here.

References

[1] R.V. Cox, Three new speech codecs from the ITU cover a range of applications, IEEE Communications Magazine (September 1997).

[2] http://www.wto.org/press/summary.htm.

[3] J. Rinde, The future direction of Internet telephony and its effect on business, Fall VON 97, Boston, http://pulver.com/von97/fall97/request.htm.

[4] Committee T1, High-bit-rate digital subscriber line (HDSL), TR No. 28, February 1994; also Generic requirements for high-bit-rate digital subscriber lines, Bellcore TA-NTW-001210.

[5] ANSI T1.413-1995, Network and Customer Installation Interfaces – Asymmetric Digital Subscriber Line (ADSL) Metallic Interface.

Joseph Rinde holds a Bachelor of Science with High Honor from Stevens Institute of Technology and a Master of Science in Computer Science from Carnegie Mellon University. From 1974 until 1983 Joe was architect of the Tymnet network as it grew from 150 nodes to over 1500 nodes. He wrote the Supervisor, the central control program for the network and later managed the development of all the network internals as well as all the CCITT interfaces. From 1983 to 1985 Joe was Director of Advanced Product Development at Amdahl's data division. From 1985 to 1989 he was a marketing Director at Equatorial Communications, the pioneer of the VSAT industry. From 1990 to 1991 Joe was Vice President of marketing for PEER Networks, a startup that designed a network based computing platform. From 1991 to 1993 Joe was an independent consultant. Among his assignments was a key roll in the development of MCI's Hyperstream Frame Relay network; a study of software quality assurance procedures by major US software development companies; development of standards for collection and exchange of accounting information for cellular systems; and a design for the integration of Tymnet and MCI's IP network. In 1993 Joe joined MCI full time as a Director in the data services engineering department. In 1995 he joined Vint Cerf's data architecture group where he has worked on universal dial in networks, world wide web based services and IP phone and Fax services.