Voice Over WLAN for Converged Enterprise Networks

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***Abstract* —** This paper is concerned with voice over wireless LAN (VoWLAN) telephony as may be applied to converged voice/data enterprise networks (ENs). The paper examines the overall architectures of ENs in general and considers how VoWLAN may be incorporated into such networks to achieve convergence. Current commercial and research activities in this area are surveyed and the advantages and disadvantages of different approaches are explored. The WINDECT (Wireless LAN with integration of professional quality DECT telephony) project is presented as a VoWLAN solution. It is shown that WINDECT differs from other approaches in its use of 'non-contention mode' WLAN access and its better adaptation to the quality of service provided by the WLAN.

Keywords-VoWLAN; WINDECT; VoIP, WLAN; converged enterprise networks (CEN);DECT

I. INTRODUCTION

The modern enterprise is organised around its data and voice communication networks which are therefore essential to its day-to-day operation. Many applications require these networks to be accessible everywhere and available at all times. Traditionally, separate networks are provided for data and voice telephony. It is now widely realised that by merging the provision of data and telephone networks, the enterprise can gain flexibility and functionality and reduce its costs. Such converged enterprise networks may be achieved in various ways as surveyed in this paper. The provision of wireless access for voice and data terminals poses special problems. The paper examines the overall architectures of ENs in general and considers how VoWLAN may be incorporated into such networks to achieve convergence.
Section II introduces enterprise networks. Section III discusses the application of Voice over IP in converged enterprise networks. Section IV shows how the WINDECT concept is applied to converged enterprise networks (CEN). Conclusions are presented in Section V.

II. ENTERPRISE NETWORKS

According to R.A. Mercer [1], an 'enterprise network' (EN) can be defined in general as a corporate-wide computer network that ties together the communications, processing and storage resources of a corporation, thereby making these resources available to users distributed throughout the corporation.

Such a network typically contains both customer-owned elements and inter-premises transport provided by a public network provider. A similar definition was given by B. Khasnabish and R. Saracco [2] who considered enterprises to be clusters of resources (both human and inanimate) which are tied together by processes which allow for interaction, synchronization, and ultimately transformation of whatever goes into a product or service delivered to customers. These processes are provided by the EN.

Traditionally, enterprise networks have been designed and used predominantly for data. Voice telephony and video communications have generally used separate networks. For example a conventional plain old-fashioned (POTs) telephone network may be used for voice traffic with private branch exchanges (PBX) fulfilling the role of 'routers'. Alternatively, voice over Internet Protocol (VoIP) networks separate from the data networks may be set up within any of the premises with bandwidth management schemes determining how the available IPN and 'public switched telephone network (PSTN) capacity is made available to data and voice traffic.

The required degree of physical integration is commonly achieved through the use of multiplexers which allow all forms of communications, i.e. voice, data, video and image to be both physically and logically integrated in a single network. In a non-converged enterprise network, the telephone service may be provided by traditional telephone terminals served by a traditional or 'software' PBX. Alternatively, VoIP telephony may be provided by LANs which are separate from those used for data. In principle, any of the LANs may be wireless.

In a converged enterprise network (CEN) as illustrated Fig.1, data, telephony and multi-media traffic share the same wired and wireless links.

VoIP is now widely used for Internet telephony and enterprise network communications. The infrastructure of an enterprise network based on wired Ethernet can be used by IP-telephones in a cost-effective way to achieve an 'all-IP' or 'total IP' solution to voice and data communications. The protocol 'H.323' is widely used for establishing and transporting VoIP traffic.

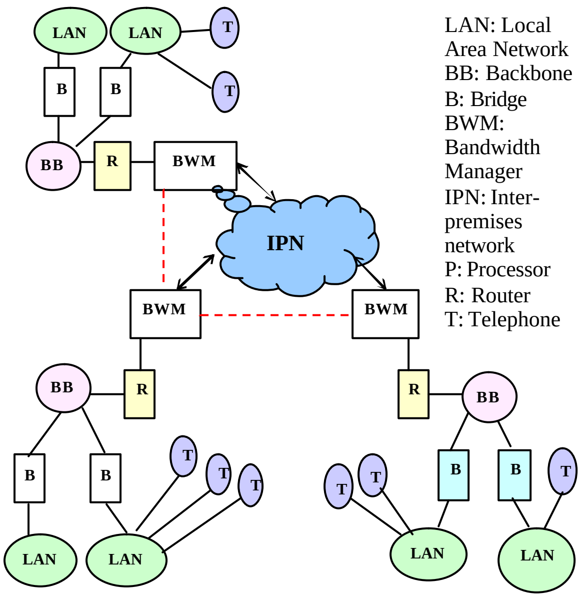

Fig.1 An Example of a Converged Enterprise Network

Alternative protocols known as the 'Session Initiation Protocol' (SIP), the 'media gateway control protocol' (MGCP), and others, are able to do the same tasks in slightly different ways.

A large number of factors are involved in achieving acceptable quality with VoIP. These factors include the choice of speech codec, the packetization strategy, the deployment of packet loss concealment, the management of delay and jitter (delay variation) and the provision of a network architecture providing the necessary QoS. Other factors include the call set-up signalling protocol, call admission control, security concerns, and the ability to traverse network address translation (NAT) and firewalls.

III. STATE OF THE ART IN VOIP FOR CEN

Many significant advancements in the performance and quality of voice over IP (VoIP) and multimedia conferencing for enterprise networks have been made in recent years. These result from improvements in the physical networks, the voice and image encoding, packet loss concealment (PLC) and other voice processing techniques. The advances have been made despite the inherent problem that computer networks, wired and wireless, were designed primarily for data and not for latency dependent interactive telephony. VoIP is widely used over wired links and is especially suitable for conveying telephone traffic between premises on IPNs, as an alternative to the use of the PSTN or dedicated telephone links.

The use of VoIP over the links from wireless access points to mobile voice and/or voice and data terminals is clearly an option for converged ENs with wireless access. Many commercial companies are basing products, i.e. wireless soft-phones, on this approach. In principle, no special equipment or software is required for this direct approach and the quality may in some cases be acceptable when there is a limited number of users who do not require the highest quality and the ability to move from the vicinity of one access point to that of another without losing connection or experiencing distortion. Normal contention mode access to the radio medium in competition with data transmissions and other VoIP users would cause unpredictable delay variation referred to as 'jitter'. The degree to which this jitter affects speech quality depends on the buffering and the reliance on packet loss concealment at the VoIP receiver. The larger the 'jitter buffer' the less will be the reliance on PLC and hence the better will be the speech quality. But this will be at the expense of greater delay.

It is generally believed [10] that a conventional IEEE 802.11b WLAN can accommodate at most about eight VoIP users without data, and that even modest amounts of data can reduce this capacity considerably. A further problem with conventional WLAN technology, as conforming to current standards, is the absence of a mechanism for achieving seamless hand-over from one access point to another. It is also difficult to conceive of a power saving sleep strategy for battery-powered devices. This is because of the unpredictability of when transmission opportunities will occur. For the same reason, it is also difficult for a device to find time to scan for new access points for possible hand-over.

Power consumption can be a severe problem with straightforward VoIP over WLAN because of the unpredictable nature of contention mode access and also because of the processing that must be done by the terminal to implement the H.323, SIP or other protocol with the demands of voice compression, encryption and other requirements. It may further be argued that VoIP is inefficient in its use of the wireless medium because of the large IP packetisation overheads. Notwithstanding all the above-mentioned disadvantages, direct VoIP calls between WLAN users may be acceptable when the communication is over a direct IP link across the CEN. But if, for example, the call is routed by a PSTN link requiring decoding and re-encoding, the resulting loss of quality and packetisation delay may become unacceptable.

The wireless terminals have to convey speech and data as efficiently as possible via the access points to the backbone within each of the premises. A fundamental problem is that VoIP systems are normally designed for wired networks with QoS characteristics that are different from those of wireless links. Packets are often delayed by wired networks, but are rarely lost. By contrast, packets will often be lost or damaged on WLAN links and VoIP schemes may not be optimal for dealing with the loss or damage. An optimal approach is to deal with the QoS of the wireless link by one mechanism, with damaged packet processing for example, and allow the wired link to have a different QoS mechanism. This is what the voice processing proposed by WINDECT [7] aims to achieve.

The requirements of VoWLAN for CENs may be summarised as follows:

1) Optimal use of the QoS delivered by the WLAN and the backbone.
2) Minimisation of the power consumption of each terminal by minimizing the processing required and allowing it to have a predictable sleep pattern.
3) Predictable performance.
4) Efficient use of the radio medium to reduce network congestion.
5) Minimisation of the effect of voice transmissions on data.
6) Low delay incurred by the wireless LAN link.
7) Seamless hand-over between APs.

Much effort has been devoted to finding solutions to difficulties with VoIP over WLAN mentioned above. One approach is to devise proprietary solutions such as that proposed by Nortel Networks [4] which introduces a priority mechanism capable of giving telephony a higher priority.

Nortel [4] claims that CENs based on IP telephony are capable of delivering acceptable performance when proprietary QoS technology referred to as “Enhanced Packet Prioritization (EPP)” is used on the wireless LANs. EPP allows IP telephone and multi-media traffic to be prioritised over heavily loaded access points. It is pointed out that users of such QoS enabled WLANs should expect less than toll quality voice some of the time in environments where there is much data communications. However, high quality voice is claimed to be achievable in ‘more controlled’ environments.

Other approaches requiring proprietary access points impose regimes of special medium access control (MAC) protocols. Such protocols impose software controlled mechanisms which determine when devices may transmit or receive, and use the WLAN's carrier sense multiple access with collision avoidance (CSMA/CA) mechanism only as a back up to guard against catastrophic failure. These new mechanisms give regular access to voice devices and do so in such a way that their packets will never be expected to collide. They also prohibit data transmissions whose timing or packet lengths would lead to collisions with voice packets or other data packets. Such software controlled access can use standard and available WLAN technology in a much more efficient way than is possible with its normal contention mode, while being fully compliant with the governing IEEE 802.11 standard. Such a scheme is the MERU Air Traffic Control (ATC) mechanism [5] that is claimed to offer 'near deterministic' channel access with regularly spaced 'TDM-like' transmission opportunities for voice channels and capacity for data. The MERU scheme is reported to be capable of supporting 30 VoWLAN calls over a normal IEEE 802.11b network, and has the further advantage of allowing devices to 'sleep' and thus conserve energy between their defined transmission slots. A proprietary solution to the hand-over problem is also provided.

There are many other proprietary systems which conform to existing standards (IEEE 802.11b etc) and may be expected to work well in applications where all users can be made to conform to the proprietary protocols.

Among many other proposals for accommodating the regular and time critical demands of voice traffic in a high data bandwidth WLAN is the '5-up' proposal by Atheros [9].

Among the companies that have produced commercial VoWLAN systems are SpectraLink and IP Blue. These systems are based on current WLAN technologies such as IEEE 802.11b and use VoIP as their voice technology. It is reported in [10] that such solutions are inefficient in their use of bandwidth and do not scale well. SpectraLink allows a maximum of 8 simultaneous calls. Above this number the WLAN is saturated, leaving no bandwidth for data. These solutions also suffer from poor voice quality, especially when the network is shared with bursty data or under heavy load. To try to address this problem, SpectraLink uses open but proprietary extensions to the 802.11 MAC to add some support for QoS. The IP Blue solution [11] is a software product for iPAQ pocket PCs. It uses a standard 802.11b card and the built-in audio support of this PDA. The software implements VoIP allowing wireless communication to standard VoIP gateways.

Cisco and Vocera are companies which have major operations in the ‘enterprise mobile VoIP’ field and have products with proprietary QoS mechanisms and integration with PBX/IP equipment marketed by Avaya, Alcatel, NEC and Nortel[10]. Wireless soft-phone providers such as TeleSym, XTEN, SJLabs and VL Inc have significant market share, but are facing huge competition as more and more companies enter the market. There are more than 400 VoIP service providers in the USA [10] and with this over-supply of services some of these providers, e.g. Vonage, Broadvoice and Net2Phone are offering Voice over WiFi (VoWiFi) handsets as a way of encouraging customer loyalty. Such VoWiFi handsets are currently manufactured by only a small number of companies which include Net2Phone, Pulver and UTStarcom, and these early devices are reported to have much room for improvement in terms of ease of use and user features [10].

Many major network operators are deploying VoIP in wireless LAN ‘hot-spots’. These include AT&T, British Telecom (BT), NTT, Verizon and Sprint. Dual mode devices offering both cellular and VoWLAN access are being proposed which are capable of roaming seamlessly between WLAN and cellular. BT, NTT Docomo and T-Mobile will soon introduce seamless roaming. BT Bluephone is a dual standard product that is being marketed in collaboration with Alcatel, Ericsson and Motorola. Its launch is imminent and it is claimed be the first such venture.

It is only recently that traditional DECT cordless phone technology has been approved in the USA. The Federal

Communications Commission (FCC) has now given it permission to operate in the 1920-1930 MHz band. In this band, DECT has a range of up to a few hundred meters, and its encryption ensures a high degree of call security. Its radio transmission scheme is designed to maximize handheld device battery life. Linksys [12] have now designed a DECT-based cordless VoIP handset using a PC running Skype. The CIT200 allows users to make VoIP phone calls from a DECT cordless handsets as well as making conventional landline calls. The Linksys CIT200 links a traditional DECT cordless phone, with 1.9 GHz TDMA air interface, to a PC running Skype VoIP via 'dongle'. This is a useful DECT application and does give voice wireless access to the facilities of an EN. It uses different frequency bands for speech and data and therefore circumvents the WLAN problems that arise with a truly converged system. However, with such an approach there is likely to be no provision for seamless hand-over.

WINDECT [7] is realising VoWLAN requirements in a fundamentally different way using the non-contention mode access mechanism 'HCCA' offered by the new QoS extended IEEE 802.11e standard. In a CEN, this will mean that the QoS of the wireless link is governed by a MAC mechanism that is specifically designed for a WLAN. The backbone can then have a different QoS mechanism suited to its requirements and capacity.

IV. WINDECT IN AN ENTERPRISE NETWORK ARCHITECTURE

The WINDECT project provides a solution for the wireless part of a converged enterprise network (EN) and other types of converged networks. The WINDECT access points (WAPs) provide the infrastructure needed for both wireless data services and wireless voice services over the same wireless network. The wireless terminals can then be (i) standard WiFi terminals accessing data services, (ii) telephone devices using just the voice services of the network, or (iii) hybrid devices which can access both the data and voice services of the network.

WINDECT has the advantage over the 'all-IP' approach of allowing different QoS mechanisms to be applied on the wireless and wired links of a network. The 'HCCA' MAC mechanism of the IEEE802.11e standard [6], as used by WINDECT, is specifically designed for this type of application and is greatly superior to 'best effort' and priority based 'differential service' alternatives as used on WLANs. In conforming to the IEEE802.11e standard, WINDECT avoids the use of proprietary MAC solutions that may not be universally accepted.

The provision of 'professional' quality telephony similar to that of traditional DECT is a goal that is best achieved by the HCCA mechanism with its reserved and guaranteed transmission capacity and centralised control at WAPs. The regular periodic transmissions under AP control allow terminals to 'sleep' between transmission opportunities and thus preserve battery power.

As mentioned above [10], over an 802.11 WLAN with standard APs, VoIP in contention mode can achieve only a limited number of calls even in the absence of data transmissions. WINDECT is capable of far more calls even when there is provision for data in the contention mode periods. Some proprietary VoWLAN architectures with specially modified MAC mechanisms, for example that by MERU Networks [5] claim to be able to cope with this requirement also and it will be interesting to compare the different approaches in practice. It is already clear that the HCCA mechanism makes very efficient use of the available RF bandwidth and should allow more simultaneous successful calls than can be achieved with contention mode MAC. Provision for data will never be less than 50% of total WLAN capacity even with the absolute maximum number of simultaneous WINDECT telephone calls.

Achieving 20 or more concurrent calls with WINDECT requires a backbone with the necessary capacity and QoS provision. The capacity can be provided by current wired IP network technology with provision for security and robustness to partial failure. If any link within a CEN has restricted capacity, for example over a wireless back-haul, WAN, or the PSTN, some QoS provision appropriate to the link may be made by conventional integrated or differential service mechanisms [8]. An IP backbone would have just one connection to each WINDECT access point, and does not require a voice and data stream separately.

V. CONCLUSIONS

Traditional VoIP approaches well suited to wired networks are not particularly well suited to voice over WLAN links. It is argued that since the QoS of wired and wireless LANs is significantly different, a better solution would be obtained by the use of different approaches for the wireless and the wired links. The WINDECT VoWLAN approach is designed specifically for WLANs and has many advantages over VoIP for conveying voice over wireless LANs.

It is concluded that the use of IEEE 802.11e and hybrid co-ordination function channel access (HCCA) is the key to a VoWLAN application in a converged enterprise network with superior voice quality, low power consumption and more efficient use of the radio medium.

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