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Quality of Service in Unified Communication

Onuiri, Ernest Enyinnaya
Department of Computer Science
Babcock University
Ilisan-Remo, Ogun State; Nigeria

Awodele, Oludele
Department of Computer Science
Babcock University
Ilisan-Remo, Ogun State; Nigeria

Abstract – The twenty-first century presents an overwhelming demand for integrated communication. It is consequent upon this that Unified Communication (UC) as an emerging technology seeks to provide a platform where people and businesses are able to interact with little or no limitations, irrespective of location. Suffice it to say that for a reasonably long time, people and especially organisations have invested heavily in implementing two parallel communication channels – one centred on a voice carrying network such as telephony, voicemail and lately, video conferencing while the other is centred on a data carrying network such as e-mails, data, instant messaging etc. However, it is worthy of note that the implementation of an integrated technology such as UC, would require a corresponding deployment of efficient Quality of Service (QoS) mechanisms. Consequently, this paper seeks to discuss the concept of QoS as it affects UC.

***Keywords**: Quality of Service (QoS); Unified Communication (UC); Real-Time (RT); Non-Real-Time (NRT)*

1.0 INTRODUCTION

Given the various kinds of media through which communication gets disseminated this days (e-mail, telephone, instant messaging, video conferencing, SMS, etc.), there is the rising need for such a platform that integrates these different technologies and interfaces through well driven communication modalities. In view of the foregoing, UC as an evolving technology seeks to do this by classifying data traffic into two distinct categories namely RT and NRT and consequently, integrating them in such a way that maximizes efficiency in the way communication flows from one point to the other.

Until recently, telephony for example was carried out using analogue phones, time-division multiplexing (TDM) trunks and legacy PBXs (Private Branch Exchanges). Today, there is a paradigm shift from the use of these technologies to ones that are more sophisticated, robust and efficient as evidenced in VoIP, facilitated by converged IP networks furnished with IP phones and the likes. Furthermore, we also see innovative services such as instant messaging and presence. This has optimized the way workers within an organisation collaborate due to the fact that communication can be efficiently effected from anywhere and at anytime.

However, this technology is not without challenges. These range from security (given the fact that being open and also flexible, IP communications are exposed to many security threats) to reliability (this is because as a business critical service, IP-based unified communications must measure up to strict reliability requirements); from QoS (because IP communications are built around a packet-based architecture, special means must be taken in order to achieve a high and acceptable QoS) to performance (the ability to provide all of the above for high volumes of RT communications which is critical for large scale deployments). [1] Our focus in this paper will be on how to implement an efficient QoS that enhances optimization in the way UC tools and services are carried out.

1.1 DEFINITION OF SOME TERMS

i. Real Time (RT): this is the actual time in which something takes place. When an event or function is processed instantaneously, it is said to occur in real-time. To say something takes place in real-time is the same as saying it is happening "live" or "on-the-fly." [2]

ii. Non-Real-Time (NRT): is a term used to describe a process or event that does not occur immediately.

iii. Presence: is a technology that lets you know where intended recipients are in RT. This application makes it possible for one to locate and identify a computing device wherever it might be, as soon as the user connects to the network. IM is a very common example. [3]

iv. Rich Presence Technology (RPT): Rich presence technology (RPT) is an enhanced form of presence awareness in which participants can determine if other users are online and if so, observe to a limited extent what they are doing and how they are doing it. Basic presence services divulge only the availability of another user. Rich presence goes further; subscribers can let others know:
- their location
- whether their device is mobile
- its specifications
- operating system
- local time
- personal messages
- current employer or client
- the level of privacy desired.
- whether the person is typing [4]

v. IP Telephony: IP telephony (Internet Protocol telephony) is a general term for the technologies that use the Internet Protocol's packet-switched connections to exchange voice, fax, and other forms of information that have traditionally been carried over the dedicated circuit-switched connections of the public switched telephone network (PSTN). Using the Internet, calls travel as packets of data on shared lines, avoiding the tolls of the PSTN. The challenge in IP telephony is to deliver the voice, fax, or video packets in a dependable flow to the user. Much of IP telephony focuses on that challenge.[5]

vi. Call Control: in telephony, call control refers to the software within a telephone switch that supplies its central function. Call control decodes addressing information and routes telephone calls from one end point to another. It also creates the features that can be used to adapt standard switch operation to the needs of users. Common examples of such features are "Call Waiting", "Call Forward on Busy", and "Do Not Disturb". An alternative name often used is call processing. [6]

vii. Unified Messaging (UM): Unified messaging (sometimes referred to as the unified messaging system or UMS) is the handling of voice, fax, and regular text messages as objects in a single mailbox that a user can access either with a regular e-mail client or by telephone. The PC user can open and play back voice messages, assuming their PC has multimedia capabilities. Fax images can be saved or printed. A user can access the same mailbox by telephone. In this case, ordinary e-mail notes in text are converted into audio files and played back. Unified messaging is particularly convenient for mobile business users because it allows them to reach colleagues and customers through a PC or telephone, whichever happens to be available. Some services offer worldwide telephone access. [7]

viii. Latency: refers to any of several kinds of delays typically incurred in processing of network data. A so-called low latency network connection is one that generally experiences small delay times, while a high latency connection generally suffers from long delays. [8]

ix. Jitters: in VoIP, is the variation in the time between packets arriving, caused by network congestion, timing drift, or route changes. [9]

2.0 UNIFIED COMMUNICATION

There are varying definitions for Unified Communications (UC). A basic definition would be “Communications integrated to optimize business processes,” but such integration can take many forms, such as: Users simply adjusting their habits, manual integration as defined by procedures and training, integration of communications into off-the-shelf tools such as Outlook, Notes, BlackBerry, Salesforce.com, and many others, or purpose-specific integration into customized applications in specific operating departments or in vertical markets such as healthcare. [10]

Also, UC is the integration of real-time communication services such as instant messaging (chat), presence information, telephony (including IP telephony), video conferencing, data sharing (including web connected electronic whiteboards aka IWB's or Interactive White Boards), call control and speech recognition with non-real-time communication services such as unified messaging (integrated voicemail, e-mail, SMS and fax). UC is not a single product, but a set of products that provides a consistent unified user interface and user experience across multiple devices and media types. [11]

Given the fact that this technology goes a long way in improving efficiency, maximizing corporate responsiveness and the facilitation of a clear reduction in the overall total cost of ownership (TCO), owners of large scale enterprises are beginning to see the need for its deployment and implementation in their networks.

One of the landmarks of UC is that it adopts the concept of presence in the way communication takes place, in that one is able to determine the location of an intended recipient before the message is sent. What this means is that an information sender knows beforehand whether to communicate in RT or NRT. Because it is almost impossible to tell whether an intended recipient is on seat, a lot of phone calls end in voicemail messages. With the concept of presence, such an uncertainty is eliminated. Furthermore, UC permits for flexibility in that an individual is able to send information on one medium and the designated recipient retrieves such information through another medium. An example of this scenario is when users receives messages via voicemail and decides to access them on their mobile phones or e-mail.

A major challenge militating against this technology is that which pertains to response time-a major tool necessary for decision making and the imminent execution of an instruction. An action that is meant to be executed in three days will be hampered by a delay in the reception of the underlying instruction and consequently cause a disorientation in the way a supposed time-critical business action is carried out. Hence, UC technology strives to minimize or eliminate totally the possibility of delay.

Components Of Unified Communication

With UC, multiple modes of business communications are seamlessly integrated. Unified communications is not a single product but a collection of elements that include:

- Call control and multimodal communications
- Presence
- Instant messaging
- Unified messaging
- speech
- Audio, video and web conferencing
- Collaboration tools
- Business process integration (BPI)
- Integrated device experience
- VoIP

Other high-end functionalities include:

- High quality of experience
- Call from applications
- High voice/video quality
- Voice integrated into applications
- Rich call management [intuitive user interface, intelligent call routing and integration with IM and video]
- Anywhere access – from web browser, from any telephone or other mobile devices
- Integrated communications tool – seamless transition between modes [11][12]

2.1 THE NEED FOR QUALITY OF SERVICE IN UNIFIED COMMUNICATION

In the world of Information Technology today, the expectations of IP networks are more than ever before on the rise. Considering that conventional IP data traffic like IP-based applications and web traffic are exponentially growing, today's networks are confronted with the need to support latency-intolerant applications such as voice and video. The challenge of network congestion is one that could easily be curtailed by mere increment in bandwidth; however, given the fact that UC integrates voice and video in its operation such a traditional measure cannot eliminate a potential problem as this. One of the most effective, efficient and relatively inexpensive ways to improve the performance of these networks is to apply some form of Quality of Service (QoS) mechanisms.

QoS is quite an elusive term since there is no finite definition for it. Depending on where, how and why it is used, people and professionals in different fields see it from different perspectives and have different understandings of it. QoS therefore, being a concept vastly used in the field of computer networking and other packet-switched telecommunication networks is used to refer to a broad collection (such as resource reservation control mechanisms) of technologies and techniques used to provide a measure of guarantees on the ability of a network to deliver predictable results. QoS technologies are intended to handle what normal bandwidth or data-compression techniques cannot – that is, guaranteed timely delivery of specific application data or resources to a particular destination or destinations. [13]

Elements of network performance within the scope of QoS often include availability (uptime), bandwidth (throughput), latency (delay), and bit error rate. Because QoS is concerned with the prioritization of traffic within a network it can be targeted at a network interface, toward a given server/router's performance, or in terms of specific applications. As a way of ensuring that network performance is optimized to a desired level, a network monitoring system should be deployed into the system.

Since core networking technologies like the Ethernet were not designed in such a way as to support prioritized traffic or guaranteed performance levels, it becomes difficult to implement QoS solutions across the Internet. QoS therefore becomes very important for new generation internet applications such as VoIP and video-on-demand. In addition, the fact that UC is a technology largely hinged on IP communications and considering the time-critical nature of RT traffic, the necessity for the fusion of QoS and UC cannot be overemphasised. In services associated with VoIP for example, occurrences such as cross-talk, interrupts, loss, echo, dropped packets, low throughput and out-of–order delivery must be eliminated whereas high bit rate, low latency, low bit error probability must be enhanced - this calls for an acceptable deployment of QoS tools and mechanisms.

For the end user, large delays are a source of concern and can cause bad echoes. It is very difficult to sustain a working conversation where the delays are too large because there is persistent interruption at both ends of the conversation. Jitter on the other hand, causes strange sound effects, although it can be put to check to some degree with the use of "jitter buffers". Packet loss causes interrupts but at a minimal scale it won't be obvious; however lots of packet loss will make sound lousy.

There is no gainsaying the fact that the backbone of any successful organization is traceable to the sophistication of communications network deployed. This is largely due to the fact that these networks transport a multitude of applications and data, including high-quality video and delay-sensitive data such as real-time voice.

The bandwidth-intensive applications stretch network capabilities and resources, but also complement, add value, and enhance every business process. Networks must provide secure, predictable, measurable, and sometimes guaranteed services. Achieving the required Quality of Service (QoS) by managing the delay, delay variation (jitter), bandwidth, and packet loss parameters on a network becomes the secret to a successful end-to-end business solution. Thus, QoS is the set of techniques to manage network resources. [14]

3.0 QoS BEST PRACTICES

In order to deploy a successful QoS mechanism in a network, it is necessary to sequentially follow the key phases listed below:

i. Define the business objectives meant to be achieved through the implementation of QoS.
ii. Analyse the service-level requirements of the various traffic classes.
iii. Design and test the adopted QoS policies.
iv. Roll-out the QoS designs that have been tested into the production-network in phases. This should be done during scheduled downtime so as to minimize interference on productive work hours.
v. Monitor service levels to ensure that the QoS objectives as prescribed by organisational needs are met at all times.

A. Defining the Business Objectives Meant to be Achieved Through the Implementation of Quality of Service

In carrying out this phase, the following questions must be answered satisfactorily:

- Is the objective to enable VoIP only or is video also required?
- If so, is video conferencing or streaming video required? Or both?
- Are there applications that are considered mission-critical? If so, what are they?

- Does the organisation wish to quash certain types of traffic? If so what are they?
- Does the business want to use QoS tools to mitigate DoS/worm attacks?
- How many classes of service are needed to meet the business objectives? [15]

B. Analyses of the Service-Level Requirements of the Traffic Classes

TABLE I: ANALYSES OF THE SERVICE-LEVEL REQUIREMENTS OF THE TRAFFIC CLASSES

VOICE	VIDEO	DATA
Predictable Flows	Unpredictable Flows	No “One-Size Fits All”
Drop + Delay Sensitive		Drop + Delay Insensitive
UDP Priority		TCP Retransmits/UDP Does Not
150ms One-Way Delay		Smooth/Bursty
30ms Jitter		Benign/Greedy
1% Loss		
17kbps-106kbps VoIP + Call-Signalling	Overprovision Stream by 20% to Account for Headers + Bursts	

C. Designing and Testing the Adopted QoS Policies

Having resolved the first two implementation phases, adopt a design that satisfies the needs earlier defined according to specification. Also, thoroughly test QoS policies prior to production-network deployment. A successful QoS policy rollout is followed by continuous monitoring of service levels and periodic adjustments and tuning of QoS policies.

As business conditions change, the organisation will need to adapt to these changes and may be required to begin the QoS deployment cycle anew, by redefining their objectives, tuning and testing corresponding designs, rolling these new designs out and monitoring them to see if they match the redefined objectives. [15]

3.1 QoS TOOLS AND SERVICE LEVELS

The implementation of QoS to enhance network quality is an end-to-end design issue. This is because network congestion can strike at any time and in any portion of the network. In view of the foregoing, QoS tools which are a set of mechanisms used to increase voice quality on data networks by lessening the amount of dropped voice packets during times of network congestion and by decreasing both the variable and fixed delays that could be encountered in a voice/video connection.

These QoS tools can be separated into the following categories:

- Classification: the first element to a QoS policy is to classify/identify the traffic that is to be treated differently. Following classification, marking tools can set an attribute of a frame or packet to a specific value.
- Policing: this is used to determine whether packets are conforming to administratively defined traffic rates and take action accordingly. Such action could include marking, remarking or dropping a packet.
- Network provisioning: Network provisioning tools accurately calculate the required bandwidth needed for voice conversations, all data traffic, any video applications, and necessary link management overhead such as routing protocols. When calculating the required amount of bandwidth for running voice over a WAN, it is important to remember that all the application traffic (that is, voice, video, and data traffic), when added together, should equal no more than 75 percent of the provisioned bandwidth. The remaining 25 percent is used for overflow and administrative overhead, such as routing protocols.
- Scheduling (Including Queuing and Dropping): scheduling tools determine how a frame/packet exits a device. Queuing algorithms are activated only when a device is experiencing congestion and are deactivated when the congestion clears.
- Link Specific Mechanisms (Shaping, Fragmentation, Compression, Tx Ring): this offers network administrators tools to optimize link utilization.[16][15]

In addition, service levels refer to the actual capabilities of end-to-end QoS; this implies the ability of a network to provide necessary services from end-to-end or edge-to-edge. The services vary in their level of "QoS strictness," which describes how firmly the service can be bound by specifiied bandwidth, delay, jitter, and loss attribute.

Three basic levels of end-to-end QoS as shown in Figure 1 can be provided across dissimilar networks. These are:

- Best-effort service – this connotes basic connectivity without guarantees. It is sometimes referred to as ‘lack of QoS’.

- Differentiated service – here, some traffic are treated better than others (e.g. more bandwidth, lower loss rate and faster handling in general). This is sometimes called 'soft QoS'.
- Guaranteed service – also called 'hard QoS' prescribes an absolute reservation of network resources for specific kind of traffic.

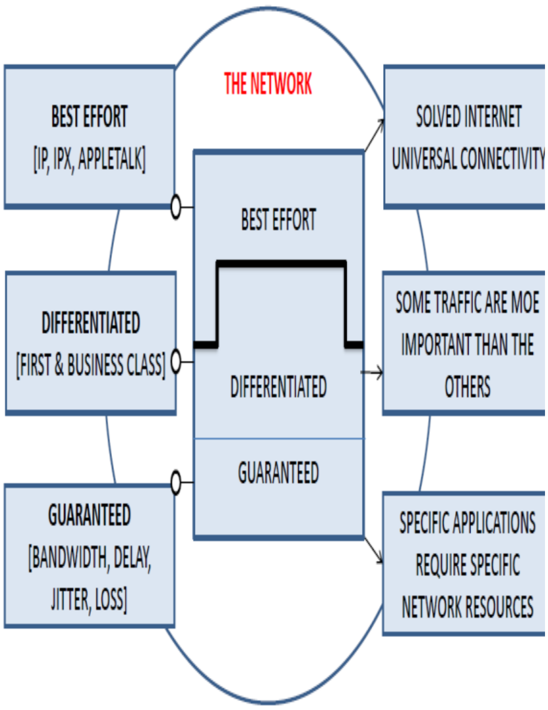

Figure 1: The three levels of end-to-end QoS

However, the decision on which type of service is appropriate for deployment in the network depends on some factors. They include:

- The business problem the customer is trying to solve.
- The scale at which upgrade of infrastructures can be realistically effected by customers.
- The cost of implementing and deploying guaranteed service will most likely be higher than the others.

4.0 CONGESTION MANAGEMENT TOOLS

One way network elements handle an overflow of arriving traffic is to use a queuing algorithm to sort the traffic, and then determine some method of prioritizing it onto an output link. Some congestion management queuing tools are as follows:

- First-In, First-Out (FIFO) queuing: this has basic store-and-forward capability. In its simplest form, FIFO queuing involves storing packets when the network is congested and forwarding them in order of arrival when the network is no longer congested. FIFO has some limitations in that queuing does not make decision with regards to packet priority; the order of arrival is what determines bandwidth, promptness, and buffer allocation. Also it does not provide protection against unpredictable applications. FIFO queuing was fundamentally a first step in network traffic control, however today's intelligent networks need more cutting-edge algorithms. This queuing method is not recommended for networks implementing UC because bursty traffic can cause long delays in delivering time-sensitive application and also to network control and signalling messages.
- Priority Queuing (PQ): also known as traffic prioritization ensures that important traffic gets the fastest handling at each point where it is used thereby giving strict priority to such important traffic. Priority queuing has the flexibly to prioritize according to the network protocol (for example IP, IPX, or AppleTalk), incoming interface, packet size, source/destination address, and so on. In PQ, each packet is placed in one of four queue based on an assigned priority: low, normal, medium or high.
- Custom Queuing (CQ): this handles traffic by assigning a specific amount of queue space to each class of packets and then servicing the queues in a round-robin fashion. It's designed was meant to ensure that various applications share the network services with allotted minimum bandwidth or latency requirements. In these environments, bandwidth must be shared uniformly between applications and users.
- Weighted Fair Queuing (WFQ): to provide desirable and consistent response time to heavy and light network users alike without adding excessive bandwidth, the solution is WFQ. It is a flow-based queuing algorithm that does two things simultaneously: It schedules interactive traffic to the front of the queue to reduce response time, and it fairly shares the remaining bandwidth among high-bandwidth flows.

WFQ ensures that queues do not starve for bandwidth, and that traffic gets predictable service. Low-volume traffic streams which comprise the majority of traffic, receive preferential service, transmitting their entire offered loads in a timely fashion. High-volume traffic streams share the remaining capacity proportionally between them. It is designed to minimize configuration effort and automatically adapt to changing network traffic conditions. The WFQ algorithm also addresses the problem of round-trip delay variability. [17] Due to its flexibility and robustness, it fits well for a network implementing the UC technology.

5.0 ADVANTAGES OF QoS IN UNIFIED COMMUNICATION

QoS when implemented in UC technology provides the following benefits:

- Resources Control – control over which resources (bandwidth, equipment, wide-area facilities, and so on) are being used at all times.
- Custom-made services – QoS enables Internet Service Providers (ISPs) to offer customized grades of services to their clients.
- Synchronization of integrated mission-critical applications – by this, bandwidth and minimum delays required by time-sensitive multimedia and voice applications are always made available; other applications using the link also get their fair share of services without hindrance to traffic that are mission-critical.
- Efficiency in the use of network resources – one is able to tell at all times what the network is being used for and that the most important traffic affecting business are being serviced.
- Connectivity Enhancement: the connectivity between devices operating in a UC setup is highly optimized.

Suffice it to say that the implementation of QoS in UC:

- Guarantees optimized bandwidth utilization for key applications and users such as video, voice and data applications while meeting performance expectations.
- Can put off the need for faster network infrastructure.
- Can help in network planning by measuring and managing traffic flow.
- Maximizes productivity by enhancing service-levels to mission-critical applications.
- Helps maintain network availability in the event of Denial of Service/worm attacks.
- Facilitates rapid response time.
- Has its greatest impact in corporate (UC) networks using VoIP and video conferencing.
- Offers greater cost reduction in the implementation of qualitative UC networks.

5.1 LIMITATIONS OF THE TECHNOLOGY

- Management-software packages are compulsory to avoid the challenges of complex configuration.
- Implementations may render some equipment and devices irrelevant.
- QoS implementation can create personnel problems over who gets the good QoS and who controls it.
- QoS implementations vary from vendor to vendor. And because QoS involves mapping certain QoS fields to other QoS fields, interoperability becomes even more complex. So at the moment, users pretty much have to use one vendor's prescription to effectively deploy QoS.
- Because QoS introduces a system of managed unfairness, most QoS deployments inevitably entail political repercussions when implemented.
- Vendors rely on a variety of underlying technologies to provide quality of service: e.g. IEEE standards 802.1P and 802.1Q. [18][19]

5.2 RECOMMENDATIONS

- To minimize the effects of non-technical obstacles to deployment, efforts must be made to address political/organisational issues as early as possible, obtaining executive endorsement whenever it is practically possible.
- There is need for uniformity in the implementation of QoS technologies. This will go a long way in enhancing QoS interoperability among heterogeneous networks where different vendor devices are deployed within the same network.
- Organisations yet to key into the deployment of UC should do so and minimize the cost of maintaining so

many communication-type networks. A well implemented UC (with good QoS mechanism) will go a long way in boosting the efficiency and collaboration of the workers within such an organisation.

6.0 SUMMARY

Technological advancements made in recent times have given rise to the world becoming a global village. UC is no exception to such advancements in that it integrates RT (such as IM, presence information, IP telephony, video conferencing, data sharing (including web connected electronic IWB's, speech recognition) and NRT (such as UM) communication in such a way that optimizes the way workers within an organisation collaborate due to the fact that communication can be efficiently effected from anywhere and at anytime.

UC adopts the concept of presence in the way communication takes place in that one is able to determine the location of an intended recipient before the message is sent. What this implies is that an information sender knows beforehand whether to communicate in RT or NRT. It also permits for flexibility in that an individual is able to send information on one medium and the designated recipient retrieves such information through another medium. Because UC integrates voice and video in its operation one of the most effective, efficient and relatively inexpensive ways to improve the performance of networks is to apply some form of QoS mechanisms.

Furthermore, there is no gainsaying the fact that the backbone of any successful organization is traceable to the sophistication of communications network deployed. UC technology brings with it more innovation in the way people and businesses communicate with great cost reduction through significant device cost savings and efficient business models enhanced by high-end devices that have wideband audio and video capabilities.

Consequent on the innovation which this technology brings is the need for a measure of transmission quality, hence the need for the implementation of QoS tools. QoS is the measure of transmission quality and service availability of networks and this quality can be determined by latency (delay), jitter (delay variation) and packet loss. With QoS tools, UC networks can be effectively managed for the transparent convergence of voice, video and data networks and also contain DoS/worm attacks.

6.1 CONCLUSION

UC is a technology largely hinged on IP communications and considering the time-critical nature of RT traffic, the necessity for the fusion of QoS and UC is of the essence. This will promote clean and clear communication outputs and generally improve on the way people and businesses interact.

REFERENCES

1. http://www.juniper.fr/us/en/local/pdf/whitepapers/2000373-en.pdf: Retrieved September 6, 2011.
2. http://www.techterms.com/definition/realtime. Retrieved September 14, 2011.
3. http://searchunifiedcommunications.techtarget.com/definition/presence-technology. Retrieved September 14, 2011.
4. http://searchunifiedcommunications.techtarget.com/definition/rich-presence-technology-RPT. Retrieved September 14, 2011.
5. http://searchunifiedcommunications.techtarget.com/definition/IP-telephony. Retrieved September 14, 2011.
6. http://en.wikipedia.org/wiki/Call_control. Retrieved September 14, 2011.
7. http://searchmobilecomputing.techtarget.com/definition/unified-messaging. Retrieved September 14, 2011.
8. http://compnetworking.about.com/od/speedtests/a/network_latency.htm. Retrieved September 14, 2011.
9. http://searchunifiedcommunications.techtarget.com/definition/jitter. Retrieved September 14, 2011.
10. UCStrategies on "What is Unified Communications?" http://www.ucstrategies.com/uc-resources/what-is-unified-communications.aspx
11. ^[a,b]Pleasant, Blair (2008-07-28). "What UC is and isn't". SearchUnifiedCommunications.com.http://searchunifiedcommunications.techtarget.com/generic/0,295582,sid186_gci1322973,00.html. Retrieved September 6, 2011.
12. http://download.microsoft.com/download/b/a/8/ba899d3f-ae72-4879-90a1-

888fd76717d9/UC_End_Use_%20Experience.ppt. Retrieved September 6, 2011.
13. http://www.networkworld.com/news/2002/0408specialfocus.html. Retrieved September 6, 2011.
14. http://www.cisco.com/en/US/products/ps6558/products_ios_technology_home.html. Retrieved September 6, 2011.
15. ^[a,b,c]http://www.cisco.com/en/US/technologies/tk543/tk759/technologies_white_paper0900aecd8019f3e0.pdf. Retrieved September 14, 2011.
16. http://www.cisco.com/en/US/products/sw/cscowork/ps2064/products_case_study09186a00800911e4.shtml#wp39829. Retrieved September 14, 2011.
17. http://www.pulsewan.com/data101/qos_basics.htm. Retrieved September 14, 2011.
18. http://www.networkworld.com/details/453.html. Retrieved September 14, 2011.
19. http://www.networkworld.com/news/2002/0408specialfocus.html. Retrieved September 14, 2011.

Onuiri, Ernest Enyinnaya is a Graduate Assistant in the Computer Science Department of Babcock University. He is a graduate of Computer Science (Technology) from Babcock University. He is a Cisco Certified Network Professional [CCNP] and a certified Security+ Professional. His areas of interest include networking and security, cloud computing, intelligent computing and bioinformatics.

Oludele Awodele holds a Ph.D. in Computer Science from the University of Agriculture, Abeokuta, Nigeria. He has several years experience of teaching computer science courses at the university level. He is currently a lecturer in the department of Computer Science, Babcock University, Nigeria. He is a full member of the Nigeria Computer Society (NCS) and the Computer Professional Registration Council of Nigeria. His areas of interest are Artificial Intelligence, Cloud Computing and Computer Architecture. He has published works in several journals of international repute.