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Networks Integration between Wireless LAN and UMTS Networks– A Brief Study

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ABSTRACT

This paper presents a brief study on issues associated with network integration between wireless LAN (WLAN) and Universal Mobile Telecommunications System (UMTS) networks. Network integration of WLAN and UMTS networks is an area that requires continuous research attention. It gives service providers the opportunity to offer additional services such as “always on service” on their heterogeneous networks for the benefit of their subscribers and for overall Quality of service improvement of the networks. Since heterogeneous networks are involved, vertical handoff (VHO) has an important role to play in achieving seamless data mobility in the next generation networks. Issues and problems of VHO have to be adequately studied and addressed if both the service providers and their subscribers should get satisfactory results such integrations. In this paper therefore, we presented an overview study of handoff management in mobile communication networks, vertical handoff requirements and the different types of network integration. Our study shows that loosely-coupled architecture of network integration far outweighs that of the tightly-coupled architecture of network integration except under a critical and specified conditions. We therefore proposed that loosely-coupled architecture should always be considered first for network integrations where ever possible. It is hoped that critical issues of loosely-coupled architecture such as network Quality of service, security, and latency will be addressed in future works.

Keywords: *WLAN, UMTS, GPRS, CDMA, TDMA, horizontal handoff, vertical handoff, mobile terminal, network integration architecture, multimode device, heterogeneous network.*

1. INTRODUCTION

Universal Mobile Telecommunications System (UMTS) is comprised of many cellular networks classified according to their generations. Some of these networks include: Global System for Mobile Communication (GSM) which belongs to the second generation (2G), General Packet Radio Service (GPRS) is another one classified as 2.5G technologies while the 3G technologies include code division multiple access (CDMA) etc. Presently, a new generation of network technologies generally known as the 3G+ or beyond 3G (B3G) or 4G are currently available and are aimed to work with multimode handheld devices [1]. The problem of integrating these heterogeneous networks for better quality of service delivery as perceived by the users is now of major interest to the research community. However, we limit our scope of study in this paper to the integration of Wireless LAN and UMTS Networks.

The release of the IEEE 802.11 WLAN standards in 1997 gave rise to a number of other related standards which form the 802.11 family of standards [2]. These standards were made to facilitate the interoperability of wireless local area networks (WLANs), and allow for the introduction of several new services. One of these services introduced is the public wireless access data networks more commonly known as “hot-spots”. The great success and massive recent deployment of WLAN technology indicates that these networks will play an important role in the development of the 4G networks [3].

To achieve the dream of universal mobile telecommunications as specified by the international telecommunications union (ITU), it is necessary to integrate WLAN and UMTS networks. This integrated network wall form part of the 4G network and it has proved to provide better services for both operators and end users. According to Albert Einstein’s aphorism, customers need not know what wireless technology, base station, access point or router they are using at a given moment, instead they only need to experience seamless service. It therefore means that technical details about seamless mobility and handoff across heterogeneous networks are simply the problem of engineers not the end users. This however calls for more research in this area in order to provide a platform for inter-network transfer of end user’s mobile terminal (MT) as easy, economical, and transparent as possible.

UMTS cellular network and WLAN hotspots are complementary wireless access technologies. Their integration could give fantastic services to meet end user’s demand for improved access to services using a single multi-mode MT. Multi-mode mobile devices (e.g. CDMA2000-WLAN PCMIA cards, WLAN- CDMA2000 PCMIA cards etc) are also fast becoming affordable and a growing number of portable computer systems such as laptops, personal digital assistants (PDAs), hand-helds etc. are now equipped to connect to different networks [4].

UMTS offers wide area coverage with high mobility support however, constrains of limited bandwidth with high cost of transferring data through this network is one of its shortfalls. Large file downloading is also difficult if not impossible with this network as there is insufficient bandwidth to support multimedia data services. On the other hand, WLAN can provide high bandwidth with low cost of data transfer but it could only cover a few kilometers and cannot provide ubiquitous coverage because; WLANs are designed for local area coverage with low mobility support [5]. In order to take the advantages offered by the two different technologies i.e. UMTS and WLAN respectively, it is necessary to integrate the two networks. WLANs are being widely deployed as WiFi hot-spots in such places as campuses, hostels, game-houses etc, whereas UMTS networks provide "always on" mobile services such as voice, short message services (SMS), e-mail, web browsing etc. The integration of UMTS and WLAN networks cannot be successful if issues of which one is handoff is not paid adequate attention. Handoff procedure between WLAN and UMTS networks must both be fast (low latency), and smooth (low packet drop) to support the wide range of necessary and emerging applications.

The rest of this paper is arranged thus: Section 2 gives the description of handoff management in communication networks, Section 3 presents the requirements for efficient vertical handoff in communication networks and Section 4 presents the types of network integrations in communication networks. The paper's conclusion and future works is presented in Section 5.

2. HANDOFF MANAGEMENT IN COMMUNICATION NETWORKS

Handoff in mobile communications refers to the ability of a mobile communications network to support MT migration dynamically while in session [6]. Handoff management on the other hand is the overall procedure of initiating and ensuring a seamless and lossless handoff of a MT from one region or network covered by one Base Station (BS) to another BS of the same or different access network (AN) [7]. For data networks e.g. WLAN network, there is a point of attachment called access point (AP) with which MT is usually registered. See Figure 1.

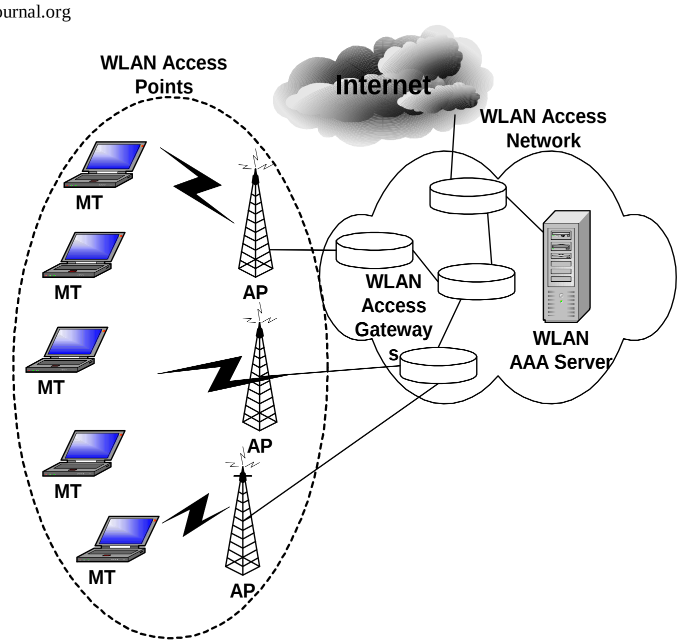

Fig 1: WLAN network

In mobile networks e.g. GPRS, CDMA2000, etc, a MT communicates with the BS that is serving the cell in which it is located. See Figure 2.

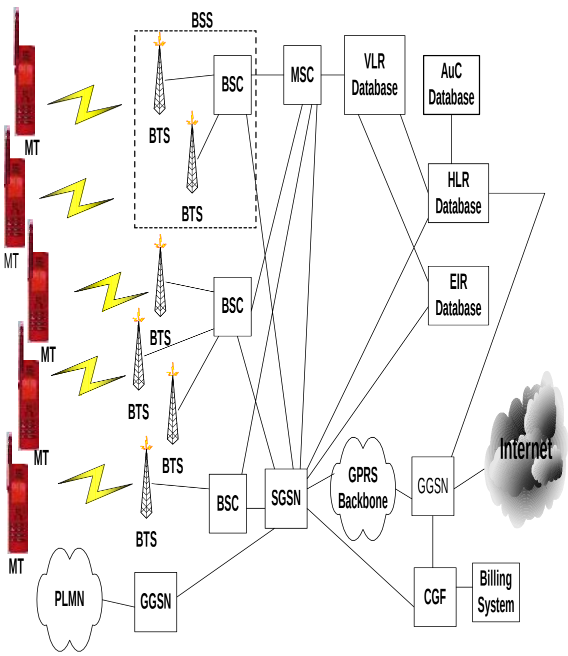

Fig 2: GPRS cellular network

As the MT moves away from the BS, the strength of the signal from this BS decreases thereby lowering signal quality. When the signal strength decreases beyond a certain predetermined value, handoff is initiated. The network hands the control of the communication of the MT over to the next BS with better signal strength. This handing over must be properly carried out in order to maintain user perceived Quality of Service (QoS) and at the same time, economizes the network resources. Successful handoff is very crucial in mobile communication networks because poor or unsuccessful handoffs introduce delay or dropped calls for voice services, and equally introduce loss of data for data services. It is known that voice service is very sensitive to delay while data service is sensitive to loss.

There are different types of handoff which could be grouped into two major categories. These are Horizontal Handoff (HHO) and Vertical Handoff (VHO). HHO is the transfer of a MT in active session from one network control point to another control of the same network technology. VHO on the other hand refers to the transfer of a MT in active session from one network to another network having a different radio system e.g. from WLAN to UMTS or vice versa. The class of handoff associated with network integration is the VHO. It plays a major role in enabling a user to use any of two different networks. VHO has two distinctions, the upward VHO and the downward VHO [8]. The upward VHO is simply a handoff to an overlay with a larger cell size and lower bandwidth/area (See Figure 3) while the downward VHO is a handoff to an overlay with a smaller cell size and higher bandwidth/area as shown in Figure 4.

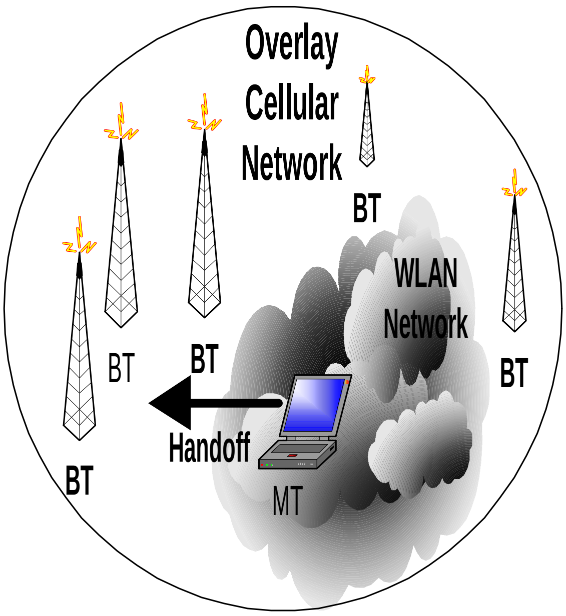

Fig 3: Upward VHO

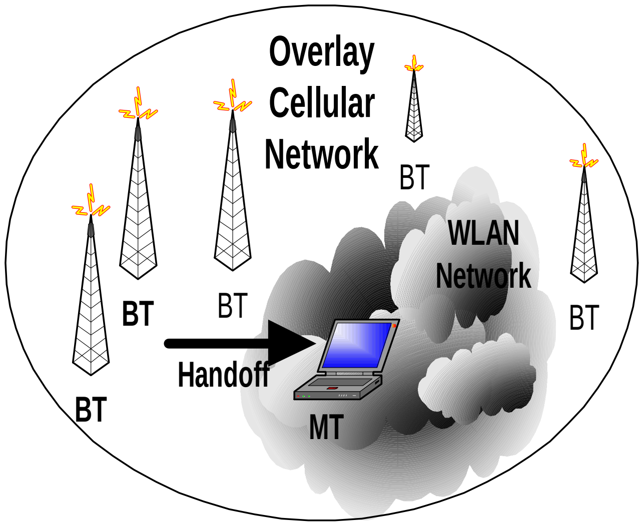

Fig 4: Downward VHO

Handoff, irrespective of which ever category consists of two phases. These are handoff initiation phase and handoff execution phase. One of the parameters that is used to decide when to start handoff process is the signal quality. The signal quality of the MT is constantly monitored by the MT or the network to determine whether handoff is to be triggered or not. Other parameters that could lead to handoff initiation are the need for higher speed or the need for the system to rearrange the resource allocation to accommodate new services. Handoff could be initiated by the MT or the network. In a mobile assisted handoff, MT constantly monitors the received signal strength. When the signal strength drops below a given threshold, the MT will signal the network to start the handoff process. In a network assisted handoff, the network monitors the signal strength of a given MT so as to determine when handoff should be performed. Handoff initiation due to cell boundary/network crossing is a frequent phenomenon in mobile communication where users are always on transit. When a MT approaches a cell boundary, signal strength from the current BS will usually drop. When the signal strength drops below a given threshold, handoff is triggered either by the network node or by the MT. the network then hands over the control of the session to the next BS. Handoff initiation due to rearrangement of resource allocation to accommodate new services is required when new services are to be executed. In this case, there may be need for rearrangement of the resource allocation to solve this problem. For instance, this type of handoff initiation could come on when a MT is about to be transferred to a new channel from the current one due to the need to increase channel capacity so as to accommodate more MT or it could be to balance the load on each BS for better performance. Handoff execution phase involves allocation of new set of resources to the MT.

In allocating resources, priority is usually given to the ongoing connection rather than a request for a new connection because it is more annoying to a user to have an ongoing connection terminated than to block a new request for connection. Three basic priority schemes for handoff execution are proposed in literature. These are reserved channel scheme, N-times retry scheme and setting up handoff queue. Reversed channel scheme reserves a few channels dedicated for handoff execution requests alone, N-times retry scheme is another priority scheme in handoff execution phase that ensures resubmission of previously unsuccessful handoff request for a specific number of times within pre-determined intervals while, setting up handoff queue is the third handoff execution phase that creates a queue for handoff requests as soon as it is noticed that there is no channel available at the moment of handoff request.

3. REQUIREMENTS FOR EFFICIENT VERTICAL HANDOFF IN COMMUNICATION NETWORKS

For effective and quality VHO to take place, it is required that certain basic needs are met and also incorporated into the handoff scheme. Some of the parameters with which VHO performance is measured are latency, scalability, drop-off and fast recovery, renegotiation or maintenance of QoS [10] after handoff is executed, minimal additional signaling and power management among others. Latency is the time taken from initiation to completion of handoff, this time should not be too long and must be proportional to the rate of mobility of the MT. Scalability of handoff scheme requires that, the handoff process should not consume too much of network resources so that overall performance does not drop due to many MTs performing handoff at the same time. Minimal drop-off and fast recovery is a measure of the time it takes a MT performing handoff to severe from the current and to reconnect to the next network node. This time should be as short as possible. Re-negotiation or maintenance of QoS after handoff execution is necessary in networks where traffic contracts have been signed between the mobile and the network. Profitability of the network depends on the QoS and therefore, the QoS of the system should be maintained after handoff is executed. Minimal additional signaling is a measure of handoff performance that requires that signaling message due to handoff should be minimal. Surplus signal should be avoided. Power management requires that the handoff process is designed in such a manner that the MT does not consume too much power due to handoff message signaling. This is because MTs are usually battery powered.

4. TYPES OF NETWORK INTEGRATION IN COMMUNICATION NETWORKS

VHO between WLAN and UMTS is closely related to the types of network integration employed. A number of network integration proposals are found in literature. These are classified according to the level of coupling between the networks [4, 6, 9, 11-15]

4.1 Tightly-Coupled Integration

In the tightly-coupled integration design, a WLAN emulates the functions of a 3G radio Access Network (AN), and therefore is treated as a 3G AN from the point of view of the 3G core network [12, 14]. Tight coupling involves viewing the WLAN network as a second Radio Network System (RNS). Tight coupling integrates the new RNS at the serving GPRS support node (SGSN). By coupling to the SGSN, WLAN resources are managed separately from the UMTS resources. As seen in Figure 5, this architecture utilizes wireless internet service provider (WISP). The WLAN (802.11) gateway network element appears to the upstream 3G core as either a packet control function (PCF) in the case of a CDMA2000 core network or as an SGSN in the case of UMTS (GPRS).

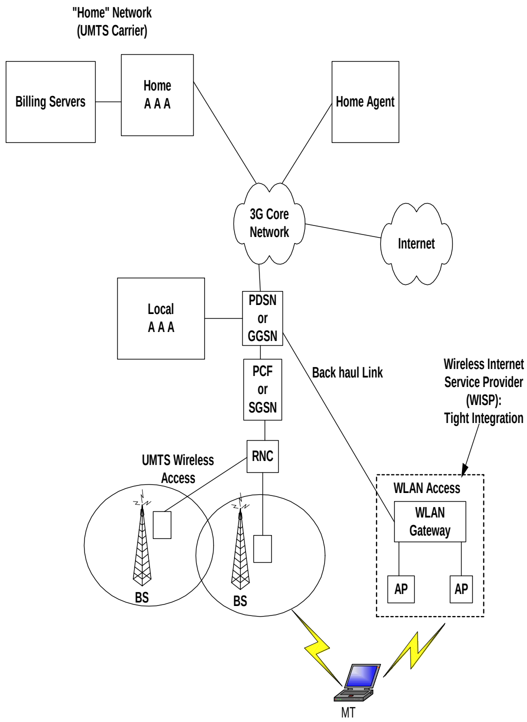

Fig 5: UMTS and WLAN integration: Tightly-Coupled architecture

The gateway of the WLAN hides the details of the WLAN network to the UMTS core network and executes all the UMTS protocols (mobility management, authentication, authorization and accounting) required in a UMTS radio access network (RAN). MT is required in this approach to implement the corresponding UMTS protocol stack on top of their standard WLAN network cards, and switch from one physical layer to the next as required. All generated traffics by clients in the WLAN network are injected into the UMTS core network using the UMTS protocols. The different network will share the same authentication, signaling, transport, and billing infrastructures independently form the protocols used at the physical layer on the radio interface. This approach however has many drawbacks because the UMTS core network interfaces are directly exposed to the WLAN networks. This means that the same operator must own the two networks, and in reality as presented in this case, independently operated WLAN islands cannot be integrated with UMTS networks. Today's UMTS networks are being deployed using carefully engineered network-planning tools, in which the capacity and configuration of each network element is calculated using mechanism which are very much specific to the technology utilized over the air interface. By injecting the WLAN traffics directly into the UMTS core network, the set up of the entire network as well as the configuration and the design of the network element such as PDSNs and GGSNs have to be modified to sustain increase in load when it happens. Furthermore, the configuration of the client device such as the MT, also presents several issues with this approach. The first being that the WLAN network cards would need to implement the UMTS protocol stack as earlier stated. Secondly, it will mandate the use of UMTS-specific authentication mechanisms based on universal subscriber identity module (USIM) or removable user identity module (R-UIM) cards for authentication on WLANs forcing WLAN providers to interconnect to the UMTS carriers' SS7 network so as to perform authentication procedures. This also implies the use of WLAN network interface cards with built in USIM or R-UIM slot or external cards plugged separately into the subscribers' devices. For all these reasons, the complexity and high cost of its configuration of the UMTS networks and the WLAN gateways would force any operator who chooses this type architecture to become uncompetitive to WLAN only WISPs. The architecture however, has an advantage of the ease to control the QoS of time sensitive traffics [11].

4.2 Loosely-Coupled Integration

In the loosely-coupled approach [11, 12, 14], the Access Point (AP) connects to a gateway which in turn connects to the distribution system and then the internet. An MT could contact UMTS network through AP, gateway, and the internet as shown in Fig. 6.

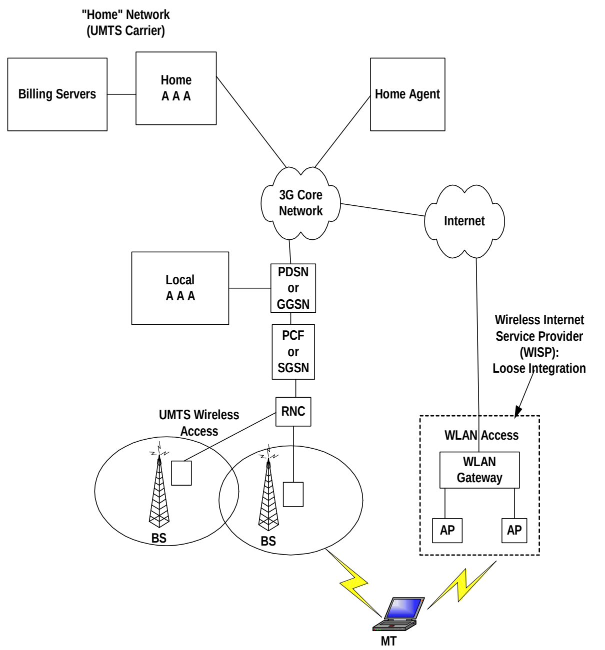

Fig 6: UMTS and WLAN integration: Loosely-Coupled architecture.

The gateway implements mobile IP, authentication, authorization and accounting (AAA) service to integrate with the UMTS home AAA server. The AAA server enables exchanging accounting information, and billing information between UMTS network and a WLAN network. The PDSN or GGSN as shown in Figure 7 implements mobile IP to support inter-PDSN or GGSN handoffs. The WLAN gateway also needs to implement mobile IP. The MT conducts handoff when its signal in one wireless network is weak or when it finds a better wireless signal in another wireless network. It is clearly seen from Figure 14 that mobile networks do not have a connection at the RAN layer instead; the networks are via the core network. In this architecture, WLAN and cellular networks are two separate ANs. The wireless access network is attached to the internet backbone, and the UMTS network is on the other hand attached to the cellular (UMTS) core network. WISP as seen from Figure 6 is connected to the gateway through the UMTS network elements either by PDSNs or GGSNs or UMTS core network switches. The gateway therefore completely shields the UMTS network from direct exposure to the internet. The user population that access the services of the WLAN gateway may include users that have locally signed on as well as mobile users visiting from other networks. The overall integration architecture is loosely-coupled because the data path of the WLAN is completely separated from the data path of the UMTS network. The high speed WLAN data traffic is never injected into the UMTS core network but the end users still achieve seamless access. This integration architecture facilitates billing and authentication but does not provide Radio Resource Management (RRM) or QoS support. This is the first step towards integrating UMTS and WLAN networks but however does not encourage the development of transparent seamless connection across multiple radio access technologies. In order to take care of the drawbacks highlighted above, different mechanisms and protocols have been designed to effectively handle authentication, billing and mobility management in the UMTS and WLAN portions of the network. However, for seamless operation to be possible, the two networks involved have to interoperate. In the case of GPRS, it is required that the WLAN gateway supports mobile IP functionalities as earlier stated to handle the integration of the networks effectively as well as providing AAA services to the inter-network with the GPRS home network AAA servers. This would enable the UMTS service provider to collect the WLAN accounting records and generate a unified billing statement indicating usage and various pricing schemes for both the GPRS and WLAN networks. At the same time the use of compatible AAA services on the two networks would allow the WLAN gateway to dynamically obtain per-user service policies from their home AAA servers in addition to enforcement and adaptation of such policies to the WLAN networks.

Since the UMTS standards do not yet include support for IETF protocols such as AAA and mobile IP, more adaptations are therefore required to have integration to UMTS networks. Mobile IP services will need to be retrofitted to the GGSNs in order to enable it have support for seamless mobility between WLAN and GPRS. Common subscriber data base would be needed for interfacing between Home Location Register (HLR) used for authentication and billing on the UMTS side of the network and AAA server for the same operation to be performed as clients roam to WLAN networks. Many advantages exist in the loosely-coupled integration architecture which includes the allowance for independent deployment and traffic engineering of WLAN and UMTS networks as UMTS service carriers can benefit from other service providers' WLAN deployments without extensive capital investment. With this advantage at the same time, they can continue to deploy UMTS network using well established engineering techniques and tools .Also, while roaming agreements with many partners can result in widespread coverage including key hotspot areas, subscribers equally benefit from having one service provider for all or any network access. As a result of this, subscribers no longer need to establish a separate account with service providers in different region or service providers covering different access technologies. Finally, unlike the tightly-coupled architecture, this architecture allows a WISP to provide its own public WLAN hot-spot to interoperate through roaming agreements with public WLAN and UMTS service providers or could also manage a privately install enterprise WLAN.

5. CONCLUSION AND FUTURE WORKS

In this paper, we presented the study of network integration between WLAN and UMTS networks. We discussed various aspects of the integration issues and particularly focused on the description of handoff management in communication networks, the requirements for efficient vertical handoff in communication networks and the types of network integrations in communication networks. Based on our extensive investigations, we came to the conclusion that, the loosely-coupled architecture offers several architectural advantages over the tightly-coupled architecture in known literature. Though there are few challenges in terms of poor QoS and security associated with the loosely-coupled architecture, our findings show that there are more to gain with loosely-coupled architecture than tightly-coupled architecture in network integration. However, where critical and specified condition exit to necessitate the use of . We therefore proposed that loosely-coupled architecture tightly-coupled architecture, we advised that it should be used. For our future work, we plan to research into QoS, security and latency issues in loosely-coupled architecture as concerned with network integration.

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