Issues of Quality of Service in Convergent Environments

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Abstract: - The emerging concept of hybrid networks and the 4th Network Generation raise several issues of network interconnection and Quality of Service. As this next generation networks consider different types of access technologies, such as GSM, Wi-Max or DVB, some very important aspects must be explored in order to make possible to deliver services through these networks with end-to-end QoS. A particular aspect of the convergent environment is the massive presence of mobile terminals as the main equipments for accessing services. This work aims to present some discussion about Quality of Service in a heterogeneous network (or convergent environment), taking into consideration the concepts of QoS Broker and Vertical Handover in order to introduce a framework for convergent environments with mobile terminals.

Key-Words: - convergence, mobility, multimedia services, vertical handover, Quality of Service, QoS Broker.

1 Introduction

Since the early times of the Internet both telecommunication and data network environments have many interfaces in order to provide access to services. The continuous evolution of the telecommunication infrastructure, information services and the types of content take into account the possibility of supporting global services from any type of access network, in any place of the planet. [1] The actual mobile access technologies, such as Global System for Mobile Communications (GSM), General Packet Radio Service (GPRS), and any other wireless networks, such as Wi-Max or Wi-Fi are present in people daily activities through mobile phones, Personal Digital Assistants (PDA) or even notebooks. According to several papers ([1], [2], [3]) the mobile terminals will be the user-preferred devices for accessing services. In this context, rather than the anytime, anything and anywhere concepts [3], the Quality of Service will be important for the provisioning of the service as the user expects.

In order to provide any type of service, over any communication platform, the integration between telecommunication systems and computer networks is an essential task. However, it is not only about connecting infrastructures, but also about considering that this integrated network will transport different types of traffic. As these integrated infrastructures will handle several types of content, such as phone calls, multimedia traffic and interactive content, it is necessary to consider issues about Quality of Service as a way to guarantee the usage of the applications provided to the end-user. It is also important to consider how to tariff the traffic and what are the appropriate business models for such heterogeneous environment [3].

This paper presents some aspects of QoS in heterogeneous networks and a framework for convergent technologies. It considers a platform for mobility, interactivity and integration between different types of communication networks. The paper is organized as follows: in section two it is discussed and defined what convergent technologies are, as well as the aspects of convergence. In section three is presented a discussion about quality of service for heterogeneous network. In section four both the framework and the different aspects about integration between different types of communication networks are presented. At last, section five brings some related works and section six has some considerations about this work.

2 Convergent Technologies

In this scenario, convergent technologies can be defined as the integration among telecommunication infrastructures, distributed computational systems and computer networks, in order to provide the use of all kind of content flows into the network, including multimedia content, independently of the terminal or the access network used by the end-user when connected.

The convergence of technologies has at least three different aspects: the network convergence, the convergence of services or medias and the convergence of end-user terminals.

Network convergence is an integrated infrastructure composed by several types of network

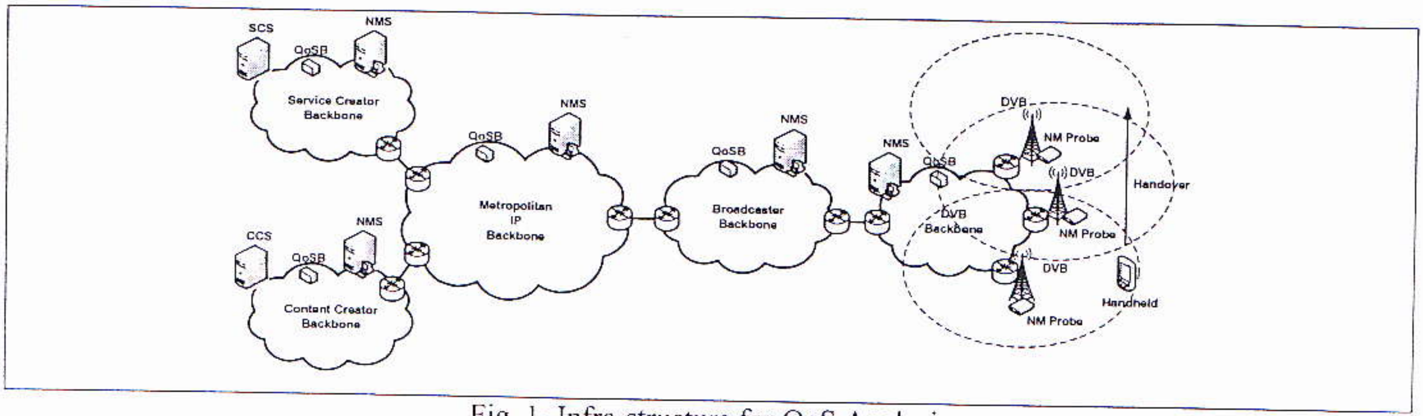

Fig. 1- Infra-structure for QoS Analysis

technologies, supporting different types of flows and services, such as audio, video and data (or any other type of multimedia traffic) simultaneously. This is very similar to the definition of the Next-Generation Networks (NGN) or the concept of 4th generation networks. However an important aspect of this infrastructure is the support of the appropriate Quality of Service aiming multimedia traffic [1], [2], [3], [4], [7].

The convergence of services implies to have the same service in more than one communication network, or the same dataflow crossing different types of telecommunication systems. As an example, some multimedia traffic could be delivered by using the PSTN (Public Switch Telephone Network), a mobile or digital TV networks. It could be even the Internet. The service must be prepared to use the most appropriate network technology available for the user. An important issue presented in the framework is how to control the resources and make then available for the services in a heterogeneous network environment.

The last aspect of the convergent technologies, the convergence of the end-user terminal means both to access different types of access networks using the same device and to interact with several types of services and contents.

In a general way, in the convergent structure different types of data flows originated from many types of networks, providing diverse services, are crossing the convergent platform and will be accessed by an end-user terminal via more than one access-network.

3 Quality of Service Issues in Heterogeneous Environment

When considering a heterogeneous environment, as shown in figure 1, it is quite clear that all these networks have their own resource controls in order to deliver any type of service to the end user, and these control mechanisms may be incompatible between them. For instance, on one hand the QoS mechanisms presented in IP networks, such as Diffserv or IntServ, are not appropriate for the heterogeneous scenarios, since they do not consider other different protocols than the IP [10], [11]. On the other hand, in the telecom networks all management is done by using an out-of-band network for signalling and network control [12], which is incompatible with the IP QoS systems. In order to build a common QoS mechanism capable of controlling the whole convergent framework, the concept of Bandwidth Broker from DiffServ technology ([13], [14]), associated with QoS administrative domains, may be used to handle not only the difference between networks, but also the restrictions presented in the legacy systems.

Although the DiffServ does not guarantee end-to-end QoS, it can be successfully used in access networks such as MNO (Mobile Network Operator) or DVB because these infrastructures have methods for pre-allocation of resources, at least in Layer 2. It means that there is available bandwidth for any established channel and the delay or jitter has no representative effect in the communication (when it is considered only the backbone) [15]. The same does not happen in an IP Backbone infrastructure.

However, it is important to have in all these infrastructures an admission control. According to [17], it is vital to establish a resource reservation mechanism, since the traffic flow of any user should follows the subscribed service requirements (SLA-Service Level Agreement). The admission control mechanism must verify the possibility of an ingress service flow going across the infrastructure. For that, it might consider both the prediction of the subnet resources allocation and the classification of traffic according with predetermined traffic classes (similarly as the DiffServ traffic classes). In order to demonstrate the necessity that any application has in following the appropriate QoS parameters, it was simulated video stream propagation into a mobile network using the CONE tool [18]. For that, some parameters of the MNO were translated to QoS parameters of the IP network. The test was composed by a MPEG 4 transmission over RTP (Real Time Protocol) without caching or buffering. In figure 2 , the transmission results can be observed when the network packet drop was 0.1%, the delay was 1.5 ms and the jitter was 0.025 ms. The MNO network did not have enough resources to transmit such video. An efficient admission control mechanism should not permit this transmission, and other network, such as DVB, should transmit that video.

Fig. 2 Video transmission over a MNO network

Taking into consideration the infrastructure of figure 1, which is based on the INSTINCT architecture [16], some QoS considerations are proposed. In the scenario, more than one Content Creation Subsystem (CCS) could exist. These contents are sent to the Service Creation Subsystem (SCS), and these portions of the structure are responsible to format all contents in an appropriate manner to the end user terminals. Therefore there is another vital component of the scenario, which is called Network Manager (NM). It receives and manages QoS information from the probes and all other network equipments. The NM is capable of building the network statistical model behaviors used by the QoS Broker in order to handle the network resources. However, the NM receives information, but does not provide any support for QoS control, which means that the NM will not handle any QoS limitation suffered by any service. Instead, the NM sends alerts and other relevant data to the QoS Broker evaluates the network state and perform QoS control based on statistical models stored in a database controlled by the QoS Broker.

The QoS control is not essential when considering only the DVB or the MNO backbones, since the structure and operation of the network guarantee some resources when a service is under transmission. When considering the Metropolitan backbone or the radio transmission itself, the effects of the delay, jitter and bandwidth becomes critical. In the metropolitan backbone several types of traffic will compete for the available resources. For the radio transmission, the resources could be limited by the effect of several types of interferences, such as rain and electromagnetic signals. In this moment the QoS control is vital for maintaining the quality in the whole network. A possible solution for that scenario is the use of QoS Broker. The QoSB will handle with the QoS parameters of the network that it belongs, and inform all necessary information to establish a connection between two or more QoS administrative domains. This concept is very similar to what the Bandwidth Broker does in the DiffServ architecture. However, for a truly heterogeneous environment some issues must be taken into consideration, especially the protocols of each network infrastructure. In the proposed scenario, the QoS Broker is composed by:

- **NM Module**: receives data of the network statistical model behaviors (such as delay, jitter, available bandwidth, packet loss);
- **Core Module**: receives data for all modules and processes how to handle the traffic and sends the appropriate parameters to configure the network equipments by Virtual Router Module [15];
- **QoSB Database**: stores the data from network statistical model behaviors;
- **Virtual Router**: sends control parameters to the network equipments ([15]), and creates a relationship between parameters used for each network technology and the respective protocols, as a way to map similar resources.
- **QoSB Interface**: receives and sends information between QoSB.

Any traffic originated in the SCS that must cross two QoS administrative domains to reach the end user device should have its resource allocation negotiated by all QoS Broker in the traffic path in order to allow a new traffic flow inside each QoS Broker network domain. For this, the QoS Broker analyzes if there are the necessary resources available in its network and selects the appropriate type of channel for the transmission of the content, as it is depicted in the figure 3.

As in the heterogeneous environment it is possible to have several types of protocols in use at the same time, the QoS Broker have the task of informing the configuration for the network equipments for mapping the characteristics of all protocols involved in the transmission of any content. For instance, if content should be transmitted from a mobile network to the DVB infrastructure (crossing the IP backbone), a mapping between the parameters of QoS of all involved protocols must be done in order to the network equipments of the traffic path interoperate respecting the SLA requirements.

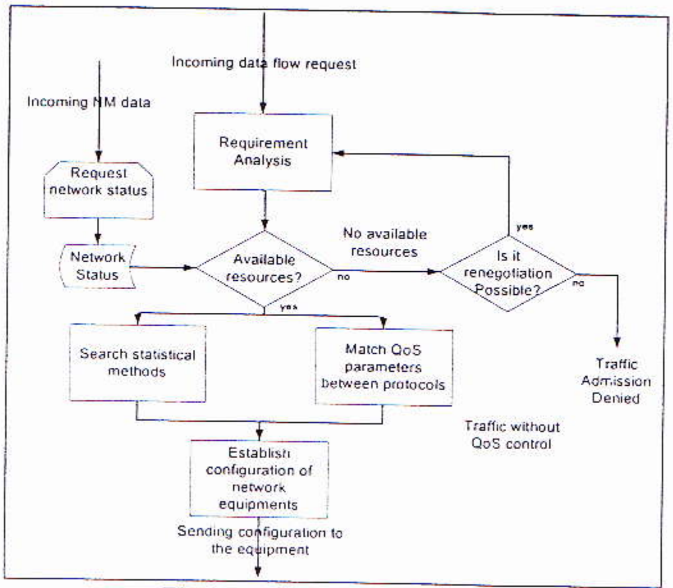

Fig. 3- QoS Broker Operation

When taking into consideration an IP backbone it is an interesting approach that the routers use the DiffServ QoS mechanism. These equipments will use the configuration data from the QoS Broker to adjust the classes of services in a way to better control the traffic flow in the network.

Taking into account the figure 3, the QoS Broker has to analyze the requirements of each new ingress traffic flow in order to verify if there are available resources, at least in one network in which the QoS Broker is connected. The requirements analysis should be based on the SLA contract of the ingress service. At the same time that the traffic is received, a constant update of the network status must be done in order to provide the correct network status to the QoS Broker. Once these two information have been gathered, the QoS Broker will have conditions to accept, or not, the traffic.

However, the QoS Broker does more than only verifying the available resources in order to establish a connection and that is due to the dynamicity of the heterogeneous network. To cover this intrinsic dynamicity, a statistical analysis of the network is vital for the QoS Broker. The main function of this step (see figure 3) is to verify how the environment behaves in average. It is obvious that the use of a statistical approach does not guarantee that the expectative of available resources indicated by the QoS Broker will match perfectly with what is happening in the network, but the use of a QoS Broker is an alternative to verify whether the networks have a considerable probability of overload. It seems a reasonable assumption because the analysis of some IP networks shows an average behaviour that does not change very much during daily data traffic. The statistical mechanism can be an interesting component of the admission control of the traffic. This statistical control could also be used in the DVB network. However, networks such DVB are much more deterministic than the IP networks, since they are based on broadcast transmissions. The knowledge about the traffic load in the DVB network will be useful, for instance, to exchange a TV transmission from the DVB to the Wi-Max network.

Another important task is how to match the QoS parameters between different protocols, since delay, jitter and bandwidth are different in each network technology, as well as they are differently mapped in heterogeneous protocols.

Despite the control, it could happen lack of resources in order to attend some SLA, when a new user request a traffic flow that cannot be provided by the administrative domain controlled by QoS Brokers. In this type of situation the QoS broker may execute two possible actions. The first one, when the SLA of the new traffic cannot be changed, the QoS Broker will reject this traffic. The other possible situation is changing the treatment of the traffic for a new permitted level. It must be considered other Classes of Service of the administrative domain in order to execute a new classification of the traffic. For instance, when a major user wants to use an administrative domain with lack of resources, the QoS broker may change the classification of other flows to a lower level priority providing the requested resources for the major user. However, the SLA already established could not be changed unless it contract permits this type of operation.

This idea could be applied, for instance, in a DiffServ domain, when the routers give specific treatment to IP packets flows based on the value of the TOS (Type of Service) field. In this case, the QoS Broker, knowing the lack of resources and contracted SLAs, can control the access router to change the TOS field of some IP packets with any priority to a lower level priority, granting access to the new major traffic flow. The users with lower priority will share a new lower level Class of Service in this administrative domain.

4 A Framework for Convergence

A framework of convergent technologies must support the content and services providers, the telecommunication systems operators and all kind of access networks in only one infrastructure. Three layers compose the heterogeneous environment of the proposed framework: the Content Delivery Systems (CDS), the Backbone and the Access Networks. These layers are presented in the figure 1.

The service and both the content generators and the content providers compose the CDS that is at the superior layer in the framework. The types of content to be transmitted by this layer are video and audio streaming, multimedia content and data. The multimedia content differs from only audio and video because it may comprise interactivity content. Some examples of service that the CDS layer could provide are:

- Instant multimedia messages;
- Business transactions;
- Interactive services, such as online games or virtual stores;
- Video conferences;
- Information services, such as Internet banking.

An important feature of the CDS layer is to produce content and services in several formats, each one with its own specific Quality of Services (QoS) requisites for its appropriate use.

Another issue of the CDS is the possibility of the applications work with different technologies of end-user devices, since there are great differences of available resources between them. A simple example is the difference between a PC and a PDA, or between a PDA and a mobile phone.

The second layer of the framework is called Backbone, which is responsible for the interconnection of all access networks (when users become connected) and the CDS. The main feature of the Backbone is to provide support for the systems interoperation and the management systems of the telecommunication operators in order to provide end-to-end QoS control and management; and support to billing and security mechanisms.

When the end-user accesses the service and content providers, he will do it by using the Access Network layer. A quite important feature of this layer is the changing of the access network technology during the transmission of the data flow in a transparent manner for the user. This means that if the user is receiving a data flow from a GPRS network and for any reason he must start receiving the data flow from a Wi-Max network, this operation must be smooth and transparent for the user. This operation is called "Vertical Handover".

4.1 Vertical and Horizontal Handover

According to [5], the handover is defined in the mobile environments as the process of changing the data flow of one base station (BS) to another one, in order to maintain the communication process. It happens when the signal of and adjacent BS is stronger than the BS that is under use. The handover can also happen nearby the cell boundary, when the quality of the service decreases [6]. In this work this type of handover is called "Horizontal Handover". This name indicates that the handover process occurs between cells of the same network technology.

However, the framework considers that one data flow can change from one type of access network to another one. For this reason, another type of handover must be considered: the "Vertical Handover". This is more than simply change the cell that is under use; it implies the change of the type of cell under use. For example, one traffic flow can start the transmission from a DVB core and for any reason the GPRS network will further continue the transmission.

In the vertical handover, some issues must be considered:

- How to guarantee the quality of service necessary for the service operation;

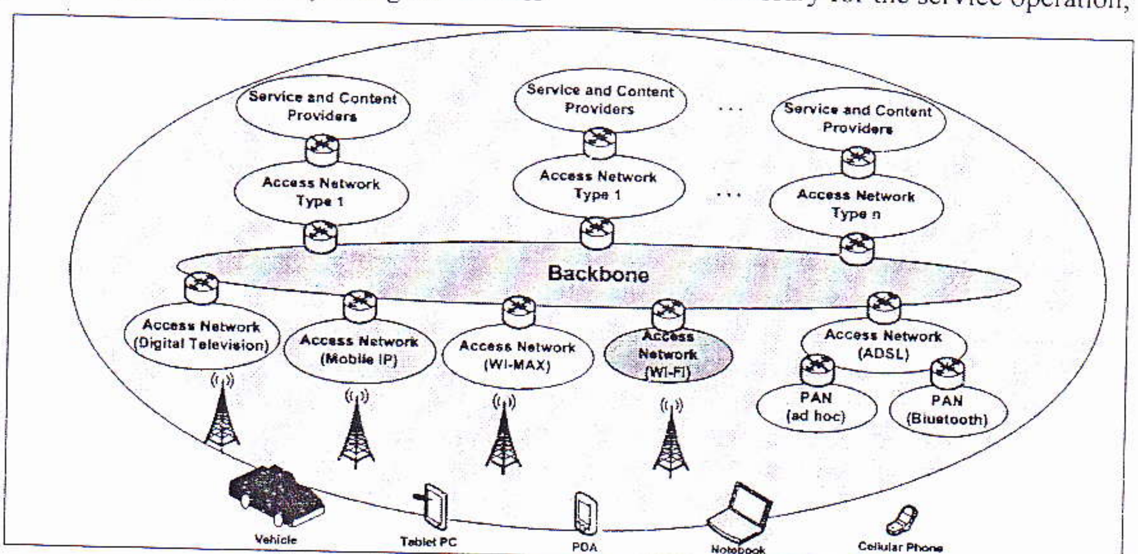

Fig. 4 – Framework for Convergent Technologies

- How to maintain the connection during the change of network technology;
- How to determine what path and what network technology is the more appropriate in order to provide the service;
- How to manage and inform to the billing processes of all telecommunication operators what resource was used in any network.

According to [7], the vertical handover will be used in the wireless access-networks, and its use will be associated to the user device, which will be able to or access these several mobile networks, or it will be reconfigurable [8].

The vertical handover brings some challenges if it takes into account the continuity of the application sessions. One of the matters is related to the Quality of Service necessary for a specific application. As it is possible to have more than one access-network available, it is a difficult task to decide what network must be used. An excessive vertical handover could interrupt the service or cause delays during the running application [9].

Although, [7] suggests a model to heterogeneous wireless network and considers the vertical handover process between wireless networks, this paper suggests that the vertical handover may occur not only in the wireless environment but also may occur in the wired and wireless network, in order to use the backbone as the way between two wireless networks, or even the vertical handover between a wireless network and a broadband network as xDSL, it is necessary taking into account the differences between the different technologies, mainly in the cases when the traffic will change from the backbone (probably a wired network) to the access-network (wireless in several cases), where the resources are lower than in the first case.

5 Related Works

References [19] and [20] are state-of-the-art researches that propose end-to-end QoS architectures for heterogeneous networks.

The EVEREST (Evolutionary Strategies for Radio Resource Management in Cellular Heterogeneous Networks) project is based on the challenges to be fulfilled within the B3G (Beyond 3rd Generation) technology concept. In this context, QoS provisioning in different Radio Access Technologies (RAT) is one of the challenges. The end-to-end QoS architecture envisaged in EVEREST considers the improvement of the QoS from the point of view of the user's mobile terminal by introducing policy-based QoS control mechanisms in the B3G network paradigm. Built around the UMTS (Universal Mobile Telecommunications Service) architecture, these control mechanisms allow the integration of several heterogeneous radio access networks (UTRAN - UMTS Terrestrial Radio Access Network, GERAN - GSM-EDGE Radio Access Network, and WLAN - Wireless Local Area Network). Each Radio Access Network (RAN) is built around a specific RAT and an extended UMTS Core Network is used to interconnect all the RANs. It is a solution based on the usage of DiffServ (Differentiated Services) QoS mechanisms in its Core Network and in its Access Networks. The project also introduces two important entities: the BB (Bandwidth Broker) and the WQB (Wireless QoS Broker). Disposed in a hierarchical way for providing scalability, the BB is in charge of the control plane of the DiffServ domain. The WQB is the counterpart of the BB for the radio part of the access network. They act both as decision points by making the admission control and the handover decisions.

The DAIDALOS (Designing Advanced Network Interfaces for the Delivery and Administration of Location Independent, Optimized Personal Services) project aims to provide an integrated architecture for multiple access technologies, incorporating wired networks (Ethernet), wireless (LANs, PANs, Bluetooth), broadcast media (DVB-S, DVB-T) and cellular technologies (W-CDMA - Wideband Code Division Multiple Access - and TD-CDMA - Time Division Code Division Multiple Access). In order to have such homogeneous platform the IPv6 protocol was chosen as the adequate convergence layer. According to [20], the IPv6 protocol creates an abstraction layer for services, by hiding technology specific parameters from advanced services. Moreover, its intrinsic support of mobility was considered quite important for the DAIDALOS system. DiffServ is used in to support QoS in the Core Network for achieving scalability and performance.

The QoS Broker (QoSB) is one of the main elements of the DAIDALOS architecture. Disposed in a hierarchical way, similarly as in EVEREST, the QoSB is responsible for controlling the access network routers according to the active sessions and for managing network resources based on the QoS requirements of the applications. It also performs load balancing of users and sessions among the available networks by setting off network-initiated handovers. This is considered a rather important feature, since it provides the means to optimize the usage of operator resources and maximize operator's income.

As EVEREST and DAIDALOS, there are other projects funded by the IST Europe Programme related to end-to-end QoS framework proposals: AQUILA (Adaptive Resource Control for QoS Using an IP-based Layered Architecture) [21], TEQUILA (Traffic Engineering for Quality of Service in the Internet, at Large Scale) [22], MESCAL (Management of end-to-end Quality of Service Across the Internet at Large) [23] and Moby Dick (Mobility and Differentiated Services in a Future IP Network) [24], just to name a few.

These projects made important contributions by designing QoS solutions over IP-based networks, however the framework proposed in this work takes in consideration the other types of networks (non IP-based) that a terminal (mobile or not) could be attached to (wired, broadcast, and cellular networks). Although the QoSB, BB and other convergence concepts of these projects are going to be used as baseline to the research, they will be revised in order to match the mobility, interactivity and convergence criteria intended to integrate in a converged way different types of communication networks.

6 Considerations

The framework for heterogeneous networks addresses several questions of the convergent environment such as quality of service, security and handover procedures. The distribution of QoS tasks between the components of the proposed architecture is necessary due to the complexity of the environment. We believe that using a QoS Broker with statistical methods to determine models of the network usage and the Network Manager to identify the best available types of channels for each transmission (by knowing the possible available services) is possible to control a subnet of the QoS administrative domain.

The QoS Broker architecture presents a possible solution for admission control in heterogeneous environment. We believe that each subnet should have at least one QoS Broker in order to provide access for it. The set of QoS Brokers should follow a hierarchical structure, similar to DNS (Domain Name System) architecture.

This paper describes an ongoing work. The methods described here are being applied and we are designing some network modules, such as the QoS Broker, in order to develop experiments using a network simulator in a way to assess the proposed architectures useful for the Instinct Project [16] partners.

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