



A 5G-Enabled E-Infrastructure for Multipoint Videoconferencing in Higher Education Institutions of Burkina Faso

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Abstract. Many actors in public institutions of higher education in Burkina Faso and around the world have used videoconferencing applications during the Covid-19 pandemic to conduct courses, pedagogical activities, participate in conferences and many other scientific activities. However, in the context of Burkina Faso where most of the actors use mobile Internet, the comfort of use of the different videoconference applications is often not satisfactory due to connectivity issues. In this paper, we propose a cutting-edge e-infrastructure to improve the usability of multipoint videoconferencing while preserving the mobility of users. The proposed e-infrastructure consists of a logical extension of the National Research and Education Network (FasoREN) access network such that multipoint videoconference calls initiated within a 5G network are routed towards FasoREN. It can be applied to any network of type FasoREN a priori and in particular to those whose actors are more inclined to use the mobile Internet.

Keywords: mobile Internet · 5G · multipoint videoconferencing · web videoconferencing · higher education · National Research and Education Network

1 Introduction

Classically, point-to-point videoconferencing required only a few hundred kbps, typically over a dedicated link. However, this traditional mode of use has the disadvantage of being doubly restrictive: not only does it require adequate infrastructure and institutional equipment, but also physical presence in the room dedicated to this service. With the development of mobile Internet but also because of the coronavirus disease (covid-19), we have witnessed an intensive use and an accelerated popularization of multipoint videoconferencing applications (Zoom, Jitsi meet, Google meet, ...). In higher education in Burkina Faso, these multipoint videoconferencing tools have been widely used to mitigate the effects of

covid-19 on academic calendars. The work of Pilabré *et al.* [1] can serve as an illustration. Although no formal survey data are available, it is safe to assume that multipoint videoconferencing is becoming a permanent fixture in the pedagogical system and materials of higher education in Burkina Faso, and that not only for distance learning but also for all types of meetings and academic activities involving geographically distant actors. On the other hand, a serious constraint remains the low speed of available connections. Indeed, public institutions of higher education in Burkina Faso do not have institutional access to the Internet. The various actors of the Burkinabè university mostly resort to individualized access to the 3G/4G mobile Internet offered by telecommunications operators. This ultimate recourse to mobile Internet has very quickly shown its limits due to the low traffic capacity of these networks in Mbps per km^2 .

Throughout the world, the answer to the problem of high-speed Internet connectivity for the world of education and research lies in the NREN (National Research and Education Network) policy. NRENs are grouped together to form continental-scale networks: for Europe, there is GEANT (Gigabit European Advanced Network) grouping together 39 NRENs with a backbone bandwidth that will be upgraded to 500 Gbps in 2020 [2], and for Africa, there is AFRICA-CONNECT with 29 NRENs to be connected [3]. AFRICA-CONNECT is made up of three regional groups namely WACREN (West and Central African Research and Education Network) for NRENs of Western and Central Africa, UbuntuNet Alliance for NRENs of Eastern and Southern Africa, and ASREN (Arab States Research and Education network) for Middle East and North Africa [4]. Burkina Faso is a member of WACREN with its NREN called FasoREN. FasoREN, like many other neighboring NRENs in the WACREN zone, is not yet operational but is still in project [4].

Based on data from a consultant's report¹, Bashir [4] reported that bandwidth requirements per student and per device are in the range of 600 kbps to 8 Mbps for various forms of videoconferencing and webinar services. Focusing on the needs of WACREN users, the work of Kashefi *et al.* [5] found that over 87% of those surveyed expressed a need to access a number of services including videoconferencing. The same study reported that 96% of the respondents would like to access services using laptops and 81% mobile devices.

There is an extensive literature on the use of videoconferencing systems for higher education around the world. Among the most recent studies, we mention a few. Indeed, authors have been interested in evaluating how students perceive a course delivered via an interactive videoconferencing system and whether they are satisfied [6]. Other studies conducted [7,8] have focused on the effectiveness of videoconferencing in education to find out the factors that can influence the learning experience. Al-Samaraie [9] was interested in comparing the three types of videoconferencing systems that are desktop videoconferencing, interactive videoconferencing and web videoconferencing (multipoint videoconferencing). To do so, he based his work on the results of various previous studies on

¹ source: data from Fox and Jones (2016); Brookings 2016 (<https://www.brookings.edu>); Arney, 2019.

the use of videoconferencing in higher education. These videoconferencing systems have been analyzed in relation to the different approaches to knowledge acquisition (constructivism and cognitivism) and their importance in terms of learning opportunities, benefits but also challenges for higher education actors has been highlighted. More recently, an evaluation of the quality of the learning and teaching experience for web videoconferencing systems such as Zoom, Skype, Teams and WhatsApp has been made [10]. From these existing works, we note the relevance of using videoconferencing in higher education and the need to build networks dedicated to the world of education and research. It is of definite interest that the technologies for implementing NRENs will be constantly upgraded. There have been no specific studies of extended NREN architectures to account for user mobility in an ecosystem of heterogeneous digital networks where mobile Internet use predominates.

In a context of higher education such as that of Burkina Faso marked by a delay to concretize its project of FasoREN, dominated by the recourse to the individualized accesses to the mobile Internet and where the use of the videoconference for the pedagogical and research activities occupies from now on a not negligible place, the present proposal wants to be a forward-looking response to the architecture of innovative digital network able to allow a more comfortable use of the multipoint videoconference via the mobile Internet for the institutions of higher education and research in Burkina Faso. The objective here is the design of a cutting-edge e-infrastructure architecture optimized for the use of multipoint videoconferencing for academic activities via the mobile Internet. By leveraging the immense potential of the 5G mobile network and opting for a dedicated NREN-type network, it is possible to design an e-infrastructure that optimizes the QoS required by multipoint videoconferencing applications.

In the rest of this paper, we discuss the theoretical support of the proposed e-infrastructure (Sect. 2), then decline and discuss the proposed e-infrastructure (Sect. 3) and end with the conclusion (Sect. 4).

2 Background Technologies and Protocols

2.1 3GPP 5th Generation Mobile Network

After 4G, 5G is the fifth generation of the 3GPP mobile network standard. It is characterized by impressive technological advances over its predecessor. Compared to 4G with a bandwidth of 100 MHz, 5G comes with a bandwidth of 1 – 2 GHz and promises speeds up to 10 Gbps in uplink against 20 Gbps in downlink. A ten times lower latency of 1 ms is promised. In terms of density of connected objects, 5G is ten times denser than 4G with 10^6 connected objects per km^2 . Its traffic capacity per area is a hundred times greater with 10 Mbps per m^2 [11, 12].

5G is also three major sets of use cases. The first is the mMTC (massive machine type communications), the second for more mobile broadband Internet (eMBB: evolved mobile broadband) and the third referred to as URLLC (ultra-reliable low latency communications). This third set supports isochronous applications such as videoconferencing. 5G offers a variety of connectivity services, including the PDU (protocol data unit) connectivity service. Through this service, the 5G network allows a mobile terminal to become a member of a data network (e.g.: a NREN). A PDU session, an association between a mobile terminal and a data network, is then established to allow the exchange of data by PDU transfer [13].

2.2 Physical and MAC Layers Technologies

In the era of 5G, suitable technology solutions must be offered to meet the objectives of high bandwidth and low latency. In this sense, cable suppliers are much more interested in innovative fiber optic cables for both core and access networks. Optical fiber is a physical medium made of glass or plastic wires that uses light to transport information over very long distances. It allows a faster connection speed, a very high throughput and a lower latency. ITU-T recommendations describe the geometrical, mechanical and transmission properties of multimode and single-mode optical cables and fibers. The current ITU-T recommendations are G.651.1, G.652, G.653, G.654, G.655, G.656 and G.657 [14]. Among them, three versions are proposed by Corning [15], the world leader in the fiber optics market. They are specified for the installation and use of innovative optical fibers. They include ITU-T G 652.D for SMF-28 Ultra fiber, ITU-T G.654.E for TFX-type fiber and ITU-T G.657.A1 for SMF-28 Ultra 200 fiber.

ITU-T G.652 describes the characteristics of an optical fiber and a single-mode cable, with zero dispersion wavelength in the vicinity of 1310 nm and 1550 nm when optimized [16]. The ITU-T G.652.D version is around 1310 nm. The ITU-T G.654 recommendation describes the characteristics of a single-mode optical fiber and cable with a cutoff offset, where the zero-dispersion wavelength is in the vicinity of 1300 nm and the cutoff wavelength is offset in the vicinity of 1550 nm [17]. Optimized, the interval of 1530 nm to 1625 nm can be reached. The ITU-T G.654.E version is around 1550 nm. ITU-T G.657 describes the characteristics of a single-mode optical fiber and cable insensitive to bending losses, with a zero-dispersion wavelength between 1260 nm and 1625 nm [18]. The ITU-T version G.657.A1 is around 1310 nm. Recommendation G.654.E is designed for high-speed, long-distance submarine and terrestrial optical networks. It is optimized for next-generation ultra high-speed optical transmissions. It is therefore an ideal candidate for backbone networks. ITU-T G.652.D and ITU-T G.657.A1 are used for broadband interconnection of buildings and homes. ITU-T G.657 is the latest release of the single-mode optical fiber recommendations and specifies the characteristics of bend-insensitive single-mode optical fibers. It is therefore the ideal choice for connecting access networks through its ITU-T G.657.A1 version.

2.3 Upper Layer Protocols

Several protocols are associated with each layer of the standard OSI and TCP/IP. Here we focus on the different upper layer protocols that are involved in the operation of videoconferencing. At the Internet layer, the IPv6 protocol, specified in RFC 8200, is designed to allow extended addressing capability with a 128-bit format, improve support for extensions and options, increase flow labeling capability, and authentication and privacy capability [19].

At the transport layer, the main protocols are TCP (Transmission Control Protocol) and UDP (User Datagram Protocol). The TCP protocol, specified in RFC 9293, allows two hosts to connect and exchange data [20]. It is a reliable protocol that is suitable for applications with connection-oriented association semantics. The UDP protocol, specified in RFC 768, allows the transmission of data in the form of datagrams without a connection [21]. This protocol provides a minimal transport, unreliable compared to TCP.

At the application layer, the Session Initiation Protocol (SIP), specified in RFC 3261, is a signaling protocol used to create, modify and terminate sessions with one or more participants [22]. These sessions include voice and video calls over IP. HTTP (HyperText Transfer Protocol) is the communication protocol between a client and a server on the World Wide Web. Its variant HTTPS (HyperText Transfer Protocol Secure), specified by RFC 2818, adds a layer of encryption with the TLS (Transport Layer Security) or SSL (Secure Sockets Layer) protocols in order to offer more secure exchanges on the Internet [23].

2.4 High Availability and Computing Environments

A data center is an infrastructure based on a network of computers and storage spaces. This storage space is used to organize, process, store and warehouse large amounts of data. A data center comprises a set of servers that are set up by an organization for its own use or made available to other organizations or individuals as a service. In this case, it is called Cloud and one has to pay to benefit from these services. Modern networks have a tendency to bring data centers closer to the users. This trend allows for better performance.

Cloud Computing is a technology and a business model that offers computing resources to individuals or organizations on demand. These shared computing resources can be servers, storage, applications, etc. It is an infrastructure that activates the main digital trends such as mobile computing, internet of things, big data, artificial intelligence for a successful digital transition [24]. There are three types of clouds: the public cloud, accessible via the Internet, the private or enterprise cloud, accessible in a private network, and the hybrid or intermediate cloud, which is a combination of the two previous types.

Multi-access Edge Computing (MEC) formerly known as Mobile Edge Computing is a standard of European Telecommunications Standard Institute (ETSI). ETSI GS MEC 003 defines its reference architecture [25]. The standard ETSI GR MEC 031 V2.1.1 (2020-10) is for the deployment of MEC technology in 5G networks. When it is deployed in a 5G network, it implements the functional entity called Application Function (AF) of the 5G network [26]. As such, MEC can ensure, with the cooperation of the PCF (Policy Control Function) entity, a particular management of the data flows for an application session, e.g.: for multipoint videoconference calls. By its principle, MEC acts as an enabler for 5G URLLC use cases. Indeed, it brings user equipments closer to the storage and computing power of the network [27]. Thus, it can be deployed in such a manner that its resources share the same location with either the base stations or the backhaul equipments of the 5G network [28]. This technology makes it actually possible for 5G operators to have their RAN (Radio Access Network) edge open to partners (e.g.: universities), giving them the opportunity to extend their services to the air interface part of the 5G network [29].

3 Proposed E-Infrastructure

3.1 Architecture and Operation

The protocol stack of the e-infrastructure as seen from the NREN end is shown in Fig. 1. Since our objective is to propose a cutting-edge e-infrastructure architecture, a technological upgrade of the network of FasoREN should be made to meet this protocol stack. The backbone network should be upgraded with TXF (Corning distribution) fiber according to ITU-T recommendation G.654.E. For the upgrade of the access network that will principally serve university campuses and halls of residence, SMF-28 Ultra 200 fiber of ITU-T recommendation G.657.A1 may be selected. Mainly made of FTTH (fiber to the home), the access network ecosystem should be completed with WiFi wireless access to take into account the mobility of users.

The proposed e-infrastructure is shown in the diagram in Fig. 2. FasoREN is provided with its own videoconferencing server installed on a virtualized data center. We propose the installation of an open source, free and secure videoconferencing server software such as Jitsi Meet [30]. The choice of a solution like Jitsi Meet aims at satisfying cost requirements. As we are about an academic environment, it is also suitable for enabling additional developments on the software through academic projects in order to meet specific needs. An interconnection of FasoREN to WACREN takes place in the proposed e-infrastructure in order to align with the general spirit of NRENs around the world. The proposed architecture also interconnects FasoREN to a 5G network. The 5G network integrates MEC servers within it.

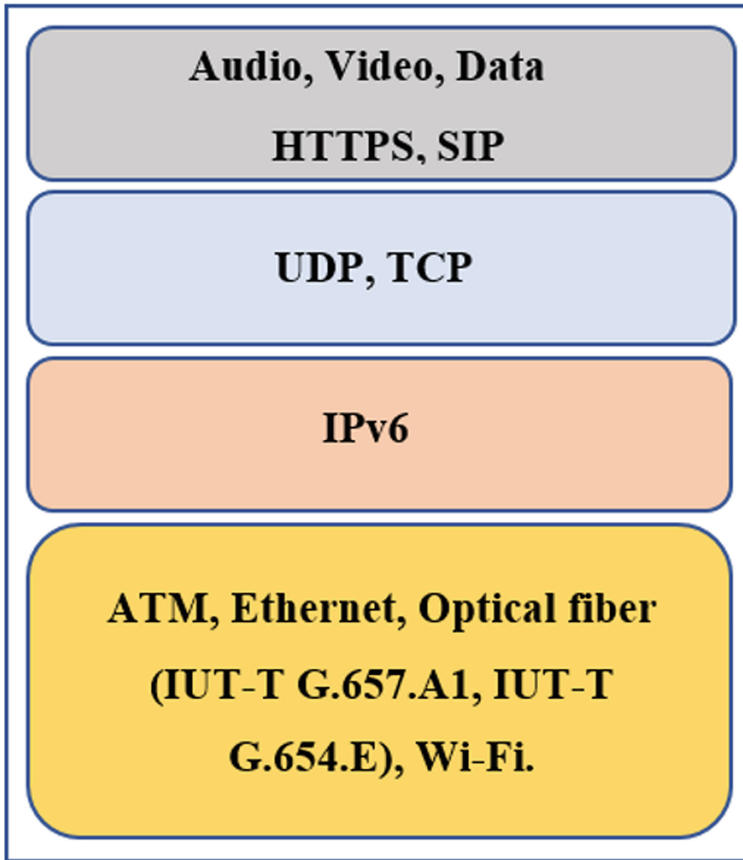


Fig. 1. Protocol stack of the FasoREN part of the e-infrastructure.

Now let's explain how this e-infrastructure will work when a multipoint videoconferencing application session is in progress with geographically distributed actors, some using the 5G network and others on university campuses for example. When a multipoint videoconferencing call is made by a user (a mobile terminal) on the 5G network air interface, their call is supported by the network. The network implements the PDU connectivity service to configure the mobile terminal to be identified according to the addressing scheme implemented in FasoREN. A PDU session is then established and the mobile terminal can transfer the PDUs of the call to the videoconferencing server of FasoREN via first a gNodeB base station and then one or more UPFs (User Plane Function) in the 5G network. The UPF is a node in the 5G network responsible for routing user data. The multipoint videoconferencing service requires the guarantee of a constant jitter to provide a satisfactory user experience. The traffic capacity per m^2 offered by the 5G network is largely large compared to that of 4G networks,

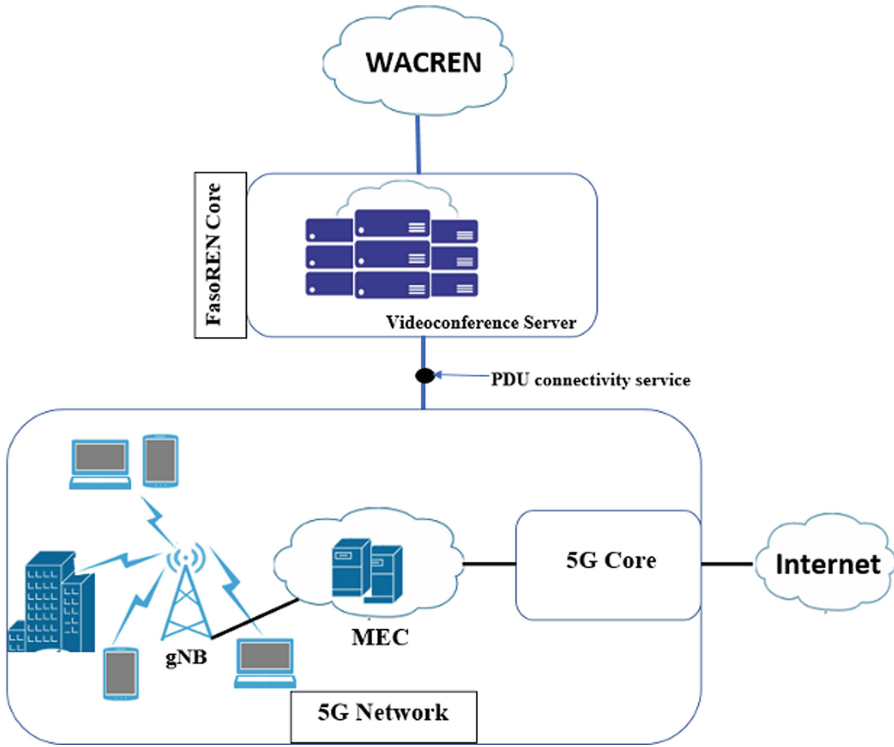


Fig. 2. Proposed e-infrastructure for multipoint videoconferencing within FasoREN.

so that PDUs could be simply forwarded following the PDU connectivity scheme. However, connectivity failures can occur for a variety of reasons and impact the overall quality of the call in progress. To maximize the likelihood of good quality of the videoconference call, the MEC server steps in to ensure that the PDUs in the videoconference call are treated appropriately according to the required quality of service. Multipoint videoconference calls initiated from FasoREN access networks (e.g.: on a university campus) are routed directly to the videoconference server using IP packet transport techniques, i.e., successive hops.

3.2 Discussion

Let’s recall that the purpose of this paper is to make a proposal for a cutting-edge digital network architecture to improve the comfort of use of multipoint videoconferencing via mobile Internet for higher education and research actors in Burkina Faso. The approach has been to draw on the technologies and protocols of the TCP/IP stack but also the opportunities offered by 5G. An e-infrastructure is ultimately proposed. It includes two distinct and autonomous digital networks in terms of their management. The 5G mobile network of a telecom operator and the FasoREN network. The 5G network provides anytime,

anywhere mobile Internet access for users in the higher education and research community. It offers PDU connectivity service allowing 5G mobile Internet users to be redirected to the FasoREN network dedicated to them for their academic activities. The choice of the MEC solution maximizes the convenience of using the multipoint videoconferencing service. An upgrade of the FasoREN network is proposed and consists of all-fiber to the end-user with additional WiFi access options.

The proposed e-infrastructure is a result that converges in its FasoREN part with technical studies [2,31] addressing the backbone topology and that have made technological upgrades. It does, however, make a difference at this point where an interconnection with the 5G network is proposed to extend NREN access to mobile Internet users. The proposed e-infrastructure therefore preserves user mobility in an increasingly heterogeneous digital ecosystem. Seen from the point of view of the multipoint videoconferencing service, it is presented as an enabler to further boost the adoption, for academic activities, of this videoconferencing service; existing studies, e.g.: [7,10], dealing with the use of this service having largely demonstrated its interest and relevance.

At this stage of the study, it is clear that the proposed e-infrastructure is technically sustainable to ensure the mobility of users and allow them to have more comfort in using the videoconferencing service. The geographical proximity of the videoconferencing server to the users, coupled with the MEC technology, is a major asset to guarantee a sufficiently constant jitter even when the number of participants in a multipoint videoconferencing session increases. On the other hand, at this stage of the study, it is premature to provide figures on, e.g.: the maximum number of participants to maintain a certain level of comfort considered good, the evolution of certain QoS parameters according to this number. A next step in this study should therefore be to design a simulation model to answer these questionings. The proposed e-infrastructure is based on the FasoREN user profile. Nevertheless, it has the advantage of being duplicable for any NREN, especially those in countries where the higher education and research actors have a similar user profile. This advantage results from the universality of the selected technologies. This same analysis applies to the videoconferencing service on which we focused in this study. In other words, any other type of digital service with the same QoS requirements can be supported. Ultimately, this study reinforces the relevance of national and regional policies to build dedicated networks for education and research. It presents an interesting opening of existing or future NRENs to the wealth of digital services and use cases that 5G abounds. It could be a harbinger of future studies to re-evaluate whether research and education actors are better accommodated with the digital environment than lecture halls and offices for face-to-face.

4 Conclusion

In the context of Burkina Faso where actors of higher education and research have widely adopted multipoint videoconferencing for various academic and scientific activities and where mobile Internet is the most widely used, the purpose of this paper is to design a cutting-edge and optimized e-infrastructure to improve the comfort of use of videoconferencing. We have proposed a digital network architecture consisting of two components. A first component consisting of an upgrade of FasoREN backbone and access network with at its core a videoconferencing server deployed in a cloud environment. A second component consisting of a 5G operator network integrating MEC servers. The 5G network, through its PDU connectivity service, allows the transfer of user data from the 5G network to the FasoREN network, thus ensuring an extension of the FasoREN access network. The proposed architecture geographically bringing the videoconference server closer to the users and implementing an enabling technology that is favorable to URLLC type use cases effectively improves the user experience of the videoconference service. This e-infrastructure provides an ideal framework for the intensive use of information and communication technologies in education and research. Thus, it will undoubtedly reduce the existing digital divide and accelerate the digital transition, particularly in the education and research sector. The future work in the framework of this study will focus on proposing and implementing a simulation protocol to quantitatively evaluate how well the proposed e-infrastructure performs.

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