Wide-scale Video Conferencing over Radio Network Infrastructure

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***Abstract* - Bringing broadband access to the communities and locations not easily accessible via standard wired technologies is still not an easy task. This is particularly highlighted in costal areas with intended coastline. In that case wireless technologies are giving flexible solutions for bridging the gap of the last mile, but bringing all the specificities of the media together as well. This is especially important having in mind highly demanding multimedia applications. One example of such solution is presented in this paper on the case of wireless broadband access for islands. Special attention is given to the network aspects of video conferencing over radio network infrastructure as one of very important tools in distance education.**

Keywords - wireless broadband; video conferencing; e-islands; distance education; WiMAX; microwave links, end-to-end delay

I. INTRODUCTION

According to European Commission's @LIS (Alliance for the information society) Programme, the proclaimed commitment of EU Commission is cooperation with the private sector and civil society in order to reduce a digital divide not only toward the developing countries, but within the structure of the EU and neighbor countries as well, [1]. This is especially important when it comes to education, where one of the main prerequisites of the modern education is development of knowledge society enabling for every child or student in remote areas to have access to the best education and new technologies without the necessity to leave home.

There is a number of well known and successful project worldwide on the field of education using information technology with the purpose of wide-spread population coverage on large geographic area. In this paper the initiatives based on the usage of two-way wireless infrastructure will be specially addressed.

First successful project using wireless infrastructure for distant education delivery in general was Ohio School of the Air [2], active between 1929 and 1937, but using just a regular radio broadcast for one-way distribution of lessons.

Excellent example of long lasting and still active project using two-way radio technology is School of the Air project in Australia [3], next year celebrating its 60th anniversary. Communication with remote students in Australian Outback was conducted via different radio technologies, dictated by the long distances needed to be covered, including remote sites on up to 800 km distances from the teachers location. As seen on Fig. 1, wireless technology used in project was evolving through the years and is including the following:

- 1951 - 2004 - two-way shortwave radio (AM, 3 - 20 MHz)

  According to [4], although users were experiencing certain problems with reception, scheduling and the lack of corresponding visual information, most schools in the Outback have purchased the cost effective equipment. The same set of radio frequencies is used by the Royal Flying Doctor Service of Australia as well, providing that way a multiple benefits for local population.

- 2004 - Present - interactive two-way broadband satellite network

  A satellite broadband is presently being implemented as a modern substitution of shortwave radio, delivering live one-way video feeds and clear two-way audio. The network includes 547 sites across New South Wales and the Northern Territory. The VSAT's (Very Small Aperture Terminal) are used on remote locations, a two-way satellite ground station with a dish antenna smaller than 3 meters.

Figure 1. Alice Springs School of the Air, historic radio and modern interactive Distance Learning Studio [5]

II. E-ISLANDS PROJECT

A. Legal context

The most recent example comes from the Adriatic Sea and is presented in details in this paper. Having in mind an extremely well-intended coastline of eastern coast of the Adriatic Sea and more than 1.000 islands spreading along it, in the sense of very light population on majority of islands, additional measures for rapid depopulation prevention had to be encouraged by the Croatian Government. First of all, a legal context with The Islands Act [6] was established in order to deal with health care, social care, pre-school, primary and secondary education, scientific research, education of island entrepreneurs, culture, environmental protection, protection of cultural heritage, etc.

One of fundamental packs of measures includes providing a broadband infrastructure for both education and local community enabling demanding network services as multimedia content delivery and video conferencing. Educational infrastructure is essential in such environment with providing access to necessary resources needed for modern educational process. Having in mind a small number of pupils per location, wide geographic scattering and season-dependent traffic connectivity, a high-quality two-way audio and visual connectivity in combination with e-content delivery between regional schools and mainland schools was nominated as a favorable solution for avoiding the necessity for the children to leave their homes in order to continue their schooling.

Therefore the Croatian Government started e-Islands project with the aim to deliver e-contents to schools on Croatian islands and acquiring the possibility of synchronous communication in regional school courses, providing that way the pupils on islands with the opportunity to have access to the same knowledge regardless of where they live. In the near future the plan is to extend the project and include local healthcare institutions in the network, as well as to provide free home broadband connections for all the pupils. As a major improvement in healthcare, this would reduce the patient transportation requirements for medical examinations and consultations outside the islands. Identical broadband coverage model is planned to be implemented on the mainland in certain areas as well, with the goal to cover schools in hinterland and geographically less accessible regions.

B. *Organizational principles*

The e-Islands project was supervised by the Croatian Academic and Research Network (CARNet), which already has a distance learning model with the video conferencing system widely used, primarily for the purposes of higher education institutions in implementation of distance courses [7].

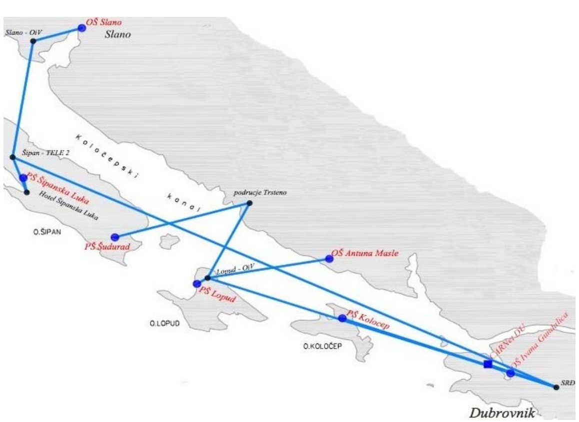

Figure 2. Network topology example, Dubrovnik area, [8]

From the organizational point of view, e-Islands project was organized as a set of point-to-point and point-to-multipoint radio connections between the administrative county centers or largest city nearby and the settlements on the islands, Fig. 2. For the purpose of the project Croatian coast is divided in four organizational and topological parts, according to the closest major network node in academic network infrastructure: Zadar area (9 schools), Sibenik area (5 schools), Split area (2 schools) and Dubrovnik area (7 schools), with 100 pupils altogether, [8].

C. *Radio network infrastructure*

The radio network infrastructure used on the project will be described on the case of Zadar area, which is at the same time the largest geographical area with the largest number of nodes as well. The basic requirement concerning connectivity between main and remote sites was to provide a full-duplex TCP/IP connection with the available bandwidth allocated according to Table I.

TABLE I. BANDWIDTH ALLOCATION PLAN

End-user	Bandwidth allocation	Technology
Mainland schools	100 Mbit/s	Optical backbone
Remote locations total	8 Mbit/s	Wireless
Remote schools	4 Mbit/s	Wireless
Remote community	4 Mbit/s	Wireless

The specific type of radio technology and detailed technical specifications of radio network backbone was designated according to the following criteria:

- Distances between main and remote locations,
- Propagation models in marine environment,
- Compliance with radio frequency spectrum allocation plan for the Republic of Croatia [9].

During the process of final calculations, both empirical and deterministic models of radio channel were used to identify two types of radio technologies for wireless backbone build-up: WiMAX (IEEE 802.16-2004 and ETSI/HiperMAN) and dedicated microwave links.

WiMAX infrastructure is used as a last loop toward the final remote location in most cases. Detailed overview of used WiMAX infrastructure used in project is presented in Table II.

TABLE II. WIMAX LINKS OVERVIEW

Parameter	Value
Frequency	3,5 GHz
Min link distance	0,2 km
Max link distance	7 km
Bandwidth guaranteed	4 Mbit/s

The equipment used for establishing WiMAX links is Alvarion BreezeMAX series, [10]. BreezeMAX series supports a wide range of network services, including Internet access, virtual private networks, voice transmission, E1/T1 connectivity, video and multimedia applications and provides advanced Quality of Service (QoS) capabilities enabling the performance of differentiated network service types with committed QoS for each service. Alvarion's BreezeMAX platform supports a variety of frequencies including 1.5 - 6 GHz bands, and leverages both FDD and TDD technologies. BreezeMAX platform consists of Base Station device and Customer Premise Equipment with the air interface supporting IEEE 802.16-2004 and future upgrade to 802.16e version of WiMAX. Further technical specifications includes OFDM 256 FFT with uplink OFDMA, FDD or TDD duplex mode and channel bandwidth in the steps of 1.75 MHz, 3.5 MHz, 5 MHz, 7 MHz and 10 MHz. One of the most important factors in favor of Alvarion BreezeMAX equipment is extended coverage feature, which was especially important in the Zadar area where the distances in the last hop were larger than in other areas, including the longest 7 km link.

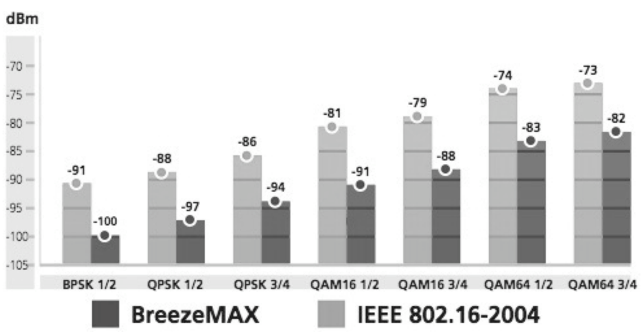

Figure 3. Alvarion BreezeMAX sensitivity improvement, [10]

According to manufacturer's declaration, an improvement comparing to IEEE 802.16-2004 standard requirement is 8-10 dBm, as shown on the Fig. 3. With available antenna types of 60º, 90º, 120º, beside omnidirectional, all required technical criteria were complied with BreezeMAX series.

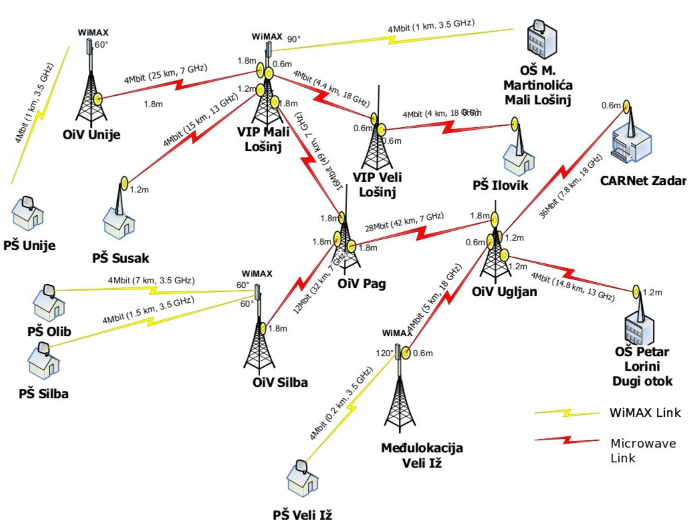

Figure 4. Radio network infrastructure, Zadar area example

Radio network infrastructure in the Zadar area is shown on the Fig. 4. According to mentioned above, a backbone of the radio network is implemented as a point-to-point or point-to-multipoint microwave links.

In the case of microwave links, Ericsson's MINI-LINK TN series is used, working on the frequencies of 7 GHz, 13 GHz and 18 GHz, providing bandwidths from 4xE1 (4x 2.048 Mbit/s) to maximum 32xE1, [11]. This system combines advanced microwave radio features with integrated traffic routing, PDH/SDH multiplexing as well as protection mechanisms on link and network level. The integrated MINI-LINK TN radio terminals provides microwave transmission operating within the 7 to 38 GHz frequency bands, utilizing C-QPSK and 16 QAM modulation schemes. It can be configured as unprotected (1+0) or protected (1+1) configuration. Concerning Ethernet functions, MINI-LINK TN provides carrier-class service, with low delay values (1-2 ms), high throughput with small packages and priority queuing. A detailed description of used microwave infrastructure is presented in Table III.

TABLE III. MICROWAVE LINKS OVERVIEW

Parameter	Value	Quantity
Connection capacity	{2, 4, 6, 8} x E1	14
	{14, 16, 18} x E1	8
	32 x E1	2
Antenna size	0,6 m	23
	1,2 m	13
	1,8 m	12
Passive reflectors	n.a.	1
Min link distance	1,2 km	1
Max link distance	49 km	1
Frequency used	7 GHz	6
	13 GHz	3
	18 GHz	15

In addition to Table III, worth mentioning is the fact that all second and third class connectivity links according to the distribution presented in Table III, namely all the links with the capacity higher than 8xE1, are configured as protected (1+1) links. Furthermore, all shorter distances were implemented using higher frequency bands - 13 GHz and 18 GHz, while longer distances were covered with using lower frequency band, 7 GHz in this case.

Having in mind a coastal area in which this project is implemented, it is important to emphasize that the large surface of the sea can cause very noticeable multipath fading.

Therefore, in the process of locations selection a great importance was paid to avoidance of the path of reflected rays. Since eastern coast of the Adriatic Sea is characterized with a low average annual rainfall, the rain attenuation was not a main concern during a fade margin calculation.

On the optical backbone, Cisco Catalyst 2950 Ethernet switches are used for radio network traffic aggregation. This part of the network infrastructure is not in the scope of this paper.

III. PRE-INSTALLATION TESTING

In the preparation phase of the project, a number of testing were done in order to establish a correlation between microwave wireless link performance and respective equipment and specific requirements for video conferencing, namely the H.323 standard. As presented in many papers [12-15], the recommendation on maximum delay allowed in video conference should be addressed very carefully and should not exceed the limitation of human perception. Accordingly, there is no noticeable effect or just a minor impact below 150 ms one-way delay of audio signal and serious impact above 300 ms delay. Video can precede the associated audio by up to 100 ms or follow it by at most 20 ms for one-way sessions [14]. Therefore an effect on human perception can be divided in three major testing groups, as presented in Table IV.

TABLE IV. VIDEO CONFERENCE SIGNAL QUALITY GROUPS, [15]

User satisfaction	Value
Good	0 ms - 150 ms
Acceptable	150 ms - 300 ms
Poor	> 300 ms

Two sets of the link termination equipment were available for network infrastructure construction and objective and subjective on-site quality assessment procedure had been chosen to test the real-time performance of both sets. In both cases, the same 8 GHz E1 microwave link with maximum of 4 hops and WiMAX last mile extension was available as a testing platform comparable to worst-case scenario in e-Islands project.

The parameters of special interest for examination were end-to-end delay, jitter and loss and they were representing the criteria for ultimate equipment selection. For that purpose, the Iperf network testing tool is used as a main inspection tool [16]. Having in mind network infrastructure topology, contributing components of end-to-end delay are including the following parts:

- Transmitter side - signal processing and transmission delay,
- Network - propagation, processing and transmission delay,
- Receiver side - buffering and signal processing delay.

Fig. 5 shows the results for the first set of equipment used in testing, where end-to-end delay in the case of both absence and presence of H.323 traffic is presented. It is clearly visible that after the H.323 traffic initiation end-to-end delay is noticeably higher, but actually never exceeds the value of 20 ms, which is very appropriate for video conferencing. However, a considerable amount of packet loss was perceived in this example as well, resulting in poor subjective quality assessment.

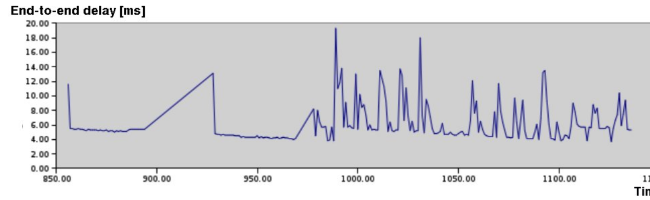

Figure 5. End-to-end delay, equipment set I

On Fig. 6 the results of second set of equipment used in test is presented. End-to-end delay values in that case in the presence of H.323 traffic are much higher than in first example, approaching in peak moments the lowest limit of link usability according to the quality group marked as poor.

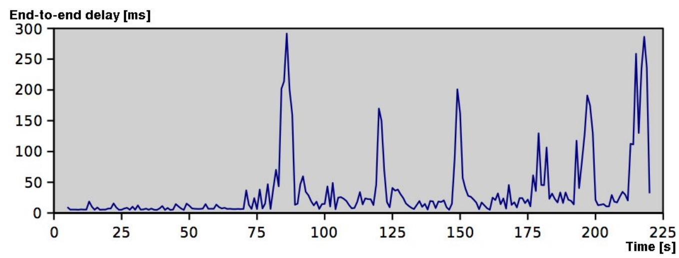

Figure 6. End-to-end delay, equipment set II

On the other hand, in second testing configuration no packet loss was registered at all. This can be explained by higher buffering capacity of the equipment used in second configuration. In addition, having in mind very good subjective quality assessment results for this configuration as well, no matter of occasional high peaks in end-to-end delay results, second configuration was chosen as an appropriate solution for link termination equipment.

IV. CONCLUSION

Video conferencing is successfully implemented as a most demanding application over the radio network infrastructure described in this paper and is being used on the regular everyday basis in elementary schools. Initial feedback from the local communities is good and having proven technology concept implemented, expansion of this approach is highly feasible.

Solution introduced in this paper in nominated as an appropriate solution for every region not easily accessible via conventional wired broadband access technologies.

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