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Multicriteria Evaluation of DVB-RCS Satellite Internet Performance Used for e-Government and e-Learning Purposes

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Abstract— **In this paper we report the findings of the EU 6th Framework Programme Project "Rural Wings" concerning the selection, performance and evaluation of the satellite internet pilot sites, based on the case studies of ten such sites in Poland. First, we present the methodology of ex-ante assessment of specific needs concerning the intensity and the scope of use of the DVB-RCS bidirectional satellite internet technology in the mountain and rural areas that led to the selection of rural sites, where the bidirectional satellite terminals were installed . Then we review the operation of the pilot sites and their final performance evaluation. We compare the rankings resulting from the initial needs assessment with that one derived from the final evaluation and analyse the divergences. Finally, we propose a learning scheme resulting from ex-post evaluation of the initial ranking procedure, which allows to assess the adequacy of the multicriteria decision-making approach applied to derive the initial pilot sites' ranking.**

I. Introduction

OVER 25 million citizens of Europe live in the remote mountain, island or rural areas, where ground-based broadband internet is hardly available - or not available at all. An improvement of the internet infrastructure is therefore necessary to bridge the digital divide by ensuring the access to information, e-government, e-commerce and e-learning applications to the members of rural communities. In some European regions, such as low-populated Bieszczady mountains in Poland, Greek islands, or northernmost parts of Sweden or Finland, the satellite internet can provide a competitive, or the only solution to cope with this problem. Consequently, the European Commission has approved a series of research projects devoted to analyze the needs and find the best technical and organizational solutions for the deployment of satellite technologies for citizens, institutions and businesses in rural areas. One of them, the 8,8 MEUR project "Rural Wings" (www.ruralwings-project.net, www.pbf.pl/ruralwings), financed by the European Union within its 6th Framework Programme, started in January 2006, with the main aim to select, launch, and maintain pilot stations of satellite internet in the bi-directional DVB-RCS (Digital Video Broadcasting - Return Channel via Satellite) technology [1], [2] in 16 countries of the world. The stations should be situated in the remote rural or mountain areas, with no – or only poor quality – broadband internet access, and serve local communities in accessing the web, supporting thus a move from the traditional agriculture to the development of innovative and sustainable agriculture and other branches of rural economy such as agrotourism. The achievement of specific goals of each pilot station, related mostly to e-government, e-learning, and e-commerce, but also to the dissemination of research carried out at some of the stations, should had been assisted, monitored, improved, advised and reported by the partners of the above project assigned the role of National Coordinator in each country. The infrastructure of pilot stations consisted of the satellite terminal (D-Star) with dedicated software and hardware. Last, but not least, most sites have been connected to Local Area Networks and WiFi networks. The technical supervision comprised measurements of the technical performance of the satellite internet terminals (D-Star) and satellite transponders (in Poland's case Eutelsat Atlantic Bird 1B), including the transmission rates for down- and uplinks, investigation of transmission failures, and tracing the sources of disturbances.

The present paper reports the methodology of evaluation of the project's results in Poland, where the Progress and Business Foundation from Cracow, an academic NGO (www.pbf.pl) has been selected to play the role of the National Coordinator. As the assessment of a network of satellite internet local hubs had not been described before in the literature, the methodology elaborated for the network of ten sites in Poland has been also presented and made available to all other Project's partners..

The paper is organized as follows: first, we will present the methodology of assessment of specific needs concerning the intensity and the scope of use of satellite internet in the DVB-RCS technology in the remote mountain areas in Southern Poland. We will review the operation of the pilot sites where the bidirectional satellite terminals were installed, then we will analyse their final performance evaluation. In the final section we will compare the rankings resulting from the initial needs assessment with that one derived from the final evaluation. While the technical criteria of needs

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assessment and evaluation were different, the target goals, i.e. intensity of use, measured as the transmission volume, the number of users and their regularity, measured by the standard deviation of the above, as well as the second goal: filling-in the gaps in the broadband coverage, and the third-one: the number of users willing to use the applications made available within the project, could be compared as *ex-ante* expectations at the stage of selecting the pilot sites, and as *ex-post* evaluation results. To make such a comparison possible, the criteria actually measured need to be transformed to the measures of the above goals, taking into account the stochastic character of the initial expectations. The method here proposed allows to derive a set of relevant needs assessment criteria from a larger set of criteria considered at the selection phase of the project. It is also possible to assess the adequacy of the multicriteria decision-making approach applied to derive the initial pilot sites' ranking. The above approach is universal in the sense that it can be applied to any similar problem, involving an initial *ex-ante* and *ex-post* rankings based on the actual performance.

II. The Needs and Analysis and Selection of Pilot Sites in the Beskidy Mountains

One of the first tasks of the project was the selection of pilot sites. Taking into account that the only geographical regions in Poland where the problems with low broadband access was related to the topography and geographical isolation were the Beskidy mountains in southern Poland, we made the decision to restrict the selection to the Małopolskie and Podkarpackie Voivodships, specifically to their counties situated in the mountains and fulfilling initial low-broadband-access assumptions.

Following the initial indications concerning the site selection criteria provided by the responsible project's partners, a site selection methodology tailored to the specific country needs was elaborated. The main three groups of selection criteria are listed below:

- **Geographical situation of sites** – according to the Project's goals, the more remote and isolated the site, the more eligible for the Project, but the diversification of geographical locations and an even distribution of sites over target areas were taken into consideration as well.
- **Existing internet infrastructure –** the pilot stations should be installed in areas without broadband facilities or – at least - the internet access provided by third parties should have lower transmission rates or be less reliable than the Rural Wings system. On the contrary, other existing IT infrastructure, such as school computer labs, LAN etc. would be of advantage for the project.
- **Availability of potential end-users** willing and capable to engage in the activities of the pilot station.

The assessment of each of the above criteria was based on the evaluation of a set measurable subcriteria, which were calculated from the data gathered in two questionnaires assessing the community and individual needs at potential pilot sites. The forms and criteria were enhanced by country-specific additional issues, in Poland relating a.o. to the ability to supply research results via satellite internet. The method to aggregate the data gathered in the questionnaires to the measures of the above criteria, as well as the choice of the multicriteria outranking method to establish the final sites' ranking was the task of the National Coordinators.

The pilot site selection was performed in four-steps:

(i) First, the country needs as a whole and the needs of regions, sectors and types of institutions were assessed in order to choose most appropriate target groups and areas.

(ii) Then the questionnaires were mailed to the selected target groups: local authorities, schools, national parks, research establishments, and business support organisations providing adult training. The data gathered were then verified during field visits and otherwise.

(iii) Taking into account the volume and the quality of data gathered, we elaborated a method to transform the questionnaire data into the measures of subcriteria. Then we used the multicriteria outranking method based on the reference sets approach [3] to establish a preliminary ranking of sites.

(iv) The selected sites, were visited in the order yielded by the outranking procedure, to present the Rural Wings project to the appropriate local authorities. Based on the technical feasibility of installing the DVB-RCS equipment at the selected sites, the results of negotiations, and the final assessment of the viability and usability of site derived from the field visits, the Selection Committee could either decide to eliminate a site from the list, e.g. in case of the lack of support from the school authorities for this site, or to change its rank. The latter might happen usually when the final decision to sign the agreement was postponed by local authorities. Then it followed the installation of DVB-RCS D-Star terminals according to the finally derived order.

Consequently, the above selection process started in Poland in early 2006 from a detailed country needs analysis in the areas of DVB-RCS technology, e-government, e-learning and other e-services and applications, which were to be provided by the project to the end-users. The above mentioned applications have been the top priorities of the „ePoland" [6] programme, first phase of which was realised prior to launching the Rural Wings project. It created thus a background for the implementation of the Project providing IT training of teachers, creating multimedia information centres, educational content and portals, electronic libraries, and content servers.

Based on the statistical data concerning the broadband access in different regions of Poland we refined the study to identify geographical areas and institutions relevant to the project, such as research institutes, national parks, local cultural centres, schools, public libraries etc. with no or only a poor-quality broadband access (nb. the dial-up connections were already commonly available via the National Telecom since the 90's). The systematically updated maps of broadband penetration were used to veryfy the needs. Future plans to establish commercial wireless broadband access by local providers were considered as well.

Thus, it was decided that the Polish sites should be situated in Southern Poland, except two potential locations in Polish off-shore research stations in Svalbard and Antarctic St.

George Island. The other potential implementation region in Northern Poland is more likely to be covered by wireless internet as it is situated in the lowlands. Furthermore, the study allowed to determine the main categories of potential satellite internet pilot stations in Poland, namely:

- public access points in local government offices, cultural centres and telecentres,
- rural schools and public libraries,
- remote research stations and national parks, and
- touristic establishments in mountain areas.

Other categories considered were policlinics and fire brigade centers in remote rural areas that perform also educational activities, for which, as it turned out, there already existed governmental or regional plans to endow them with modern IT infrastructure, including broadband access.

As only two sites had to be installed in phase I of the project, the country needs analysis was extended and updated prior to the phase II in 2007. The needs analysis in the areas of DVB-RCS technology, e-government, e-learning and other Information Society services, technologies and applications, has been performed using the IST foresight results for Poland elaborated during the 5th Framework Programme FISTERA project [5],[6], while the analysis of future applications has been performed within the ERDF-financed foresight project quoted in the footnote above.

In the second step, the questionnaires were distributed to over 400 institutions in Małopolskie and Podkarpackie regions (Voivodships) identified as potential pilot sites. From over 120 replies, about 70 seemed to be eligible pilot stations. Individual site visits and interviews reduced this number to about 40, eliminating non-public institutions or multiple institutions in one village.

Further, in Step (iii), the sites' selection criteria and selection methodology have been refined using the multicriteria analysis. We have elaborated a dedicated multicriteria site selection methodology which uses the reference sets approach [3] and takes into account the specific Poland's needs.

A preliminary ranking using a set of target reference points was established, so that for each of the above listed four categories of pilot stations a model pilot site was defined, characterized by desirable values of each of the above three metacriteria. The models played the role of non-attainable (ideal) target reference points in the above outranking method, namely for each of the complete questionnaires received form an eligible pilot site we calculated the distance to the model target point representing an appropriate category. At the same time minimal requirements, specified within the Project, had to be fulfilled by all sites considered; they played the role of status quo reference points, as defined in [9] and had been used as constraints. Ten sites with the highest distance scores were thus found to be the candidates for the 1st phase installations of the Rural Wings project in Poland. Only two of them had to be actually installed, while the others could remain candidates for the subsequent phases two and three.

TABLE I.
THE INITIAL RANKING OF RURAL WINGS PILOT SITE CANDIDATES IN POLAND

Rank	Name of the Pilot Site	Place, Region	Type	Users	Employees with IT background	Internet available
1.	Arctowski Research Station	St. George Island, Antarctica	Research	a) researchers b) visitors	All researchers at the Station	NONE
2.	Babiogórski National Park	Zawoja, Małopolska (Beskidy Mts.)	Wildlife reservation/ Research / Tourism	a) scientists b) visitors c) local community members	Two IT-specialists	Dial-up connection 64Kb/sec (DSL)
3.	Polish Polar Station – Hornsund	Hornsund Fjord, Svalbard	Arctic Research	a) scientists c) visitors	All researchers working at the Station	(Satellite, high disturbances)
4.	Polana Primary School	Polana, Podkarpackie (Bieszczady Mts.)	Primary School	a) school-children b) farmers c) tourists	One IT teacher responsible for the hardware and LAN	NONE
5.	Magurski National Park	Krempna, Małopolska, Beskid Niski Mts.,	Wildlife reservation/ Tourism/ Research	a) scientists b) visitors c) local community members	One IT-engineer	Radio ADSL connection (disturbances)
6.	Gładyszów Primary School	Gładyszów South-Eastern Małopolska	Primary School	a) school-children b) farmers c) tourists	One IT teacher responsible for the hardware and LAN	Ground-based ADSL connection

Source: Progress & Business Foundation (2009)

In the final, fourth, phase of the selection procedure we investigated the synergy with other projects of similar nature and goals as Rural Wings, that - if carried out in the same area - would constitute a challenge to the Project. Each such situation had been investigated in detail and the results actually influenced the final ranking. For instance, sites endowed already with broadband access from earlier programmes, such as “Ikonka” or “Interkl@sa”, were not taken into account for the Rural Wings pilot phase, that allowed to reduce the number of initial highest-ranked candidates to six.

During the selection process we took into account new opportunities that arose from the contacts with the leaders of local action groups, institutions hosting pilot sites, and local administration. A possibility to establish bi-directional scientific and educational data interchange between several Polish research stations: the polar station in Hornsund, the Antarctic research station on St. George Island, the Magurski, and Babiogórski National Parks, has been investigated as an additional chance and added value of the Project requiring the use of specialised software tools. The local administration representatives have been interested mostly in e-government applications and in teaching the members of local communities how to use them.

The results of the above presented selection procedure – six locations in the Antarctica, Svalbard and in the Beskidy mountains - are presented in Tab.1 above.

By the end of June 2006 the phase I of the pilot sites selection was completed and working contacts established with the representatives of all selected candidate sites. However, the Antarctic Arctowski Research Station, ranked 1, could not get the satellite connection because of the technical infeasibility of the Atlantic Bird 1 B satellite to reach the St. George Island. Furthermore, heavy snowfalls, that came as

early as in September, made the installlation of the D-Star terminal in Hornsund, Svalbard, impossible. Finally, sites ranked 2 and 4: the Babiogórski National Park and Polana Primary School turned out to be successful winners of the phase I of the selection process. A similar procedure has been performed for the 2nd phase pilot sites, yielding a list of next-best eight pilot stations. All they are presented in the next Sec.3.

III. The operation of the DVB-RCS pilot sites in Poland

First two pilot sites, selected within the above described procedure, were installed in March 2007: the Babiogórski National Park with the site in the Park's headquarters in Zawoja, Beskidy Mountains, Małopolskie Region, and the Polana Primary School, situated in the Bieszczady Mountains, Podkarpackie Region. The selection of sites performed for the second project period yielded eight subsequent sites. All selected sites are shown in the Fig.1 and Tab.2.

The phase II installations started in two municipalities in in the Beskidy Mountains in Małopolska in 2008: Wiśniowa with the sites at the Lubomir mountain – the didactic astronomical observatory of the Jagiellonian University and in the Wiśniowa Secondary School, and the municipality of Raba Wyżna with sites at the Rokiciny Podhalanskie Telecenter and at the Public Library in Skawa. Following a needs' analysis, the sites have been endowed with the software and hardware suitable for the selected scenarios of use, and the terminals were connected to WiFi networks.

The remaining four pilot sites were established at the Primary School in Nowy Łupków, the Secondary School No. 9 in Kęty, finally, the Primary Schools in Myczkowce and Harkabuz in 2009. The latter sites are situated in the mountains as well: Kęty in the Beskid Żywiecki Mountains, Nowy Łupków and Myczkowce in the Bieszczady Range in South-Eastern Poland, and Harkabuz in the Central Beskidy Mountains. Basic characteristics of all above-mentioned pilot sites is presented in Tab.2 on the next page.

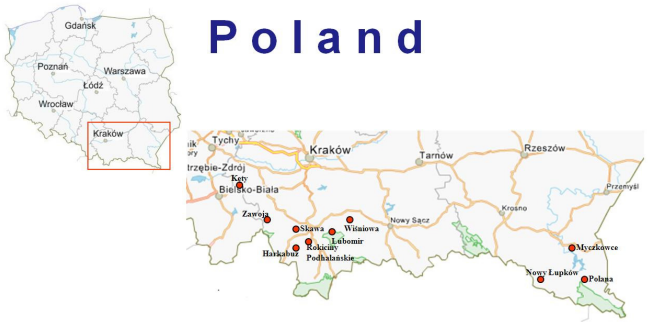

Fig 1. The situation of Polish satellite internet pilot sites selected for the Rural Wings project

The technical and training support activities provided by the National Coordinator were supplemented by monitoring the operation of the pilot sites and collecting the data for final evaluation. They included a.o. on-site consultancy, measurement of transfer rates, consulting concerning hardware of satellite terminals and WiFi installations, monitoring the use of applications supplied by other project's partners.

Further needs analysis concerning the hardware and software, based on the actual users' needs elicited during the pilot phase, had been carried out.

The National Coordinator's team reviewed the users' scenarios available in the Rural Wings project in order to plan a most effective project implementation and to assist the users. A new package "Improving internet access to public services and the electronic office (e-government) features learning" was defined and included in the scenario portfolio as this has been expected to be the most relevant issue in Poland at time when the project was carried out. Then the recommended scenarios for each pilot sites were chosen by the local community leaders assisted by the national Coordinator. The initial assignment of scenarios is presented in Tab. 3 in the next Section.

The *ex-ante* expectation concerning the use of satellite internet shown in Tab.3 served as a base for the *ex-post* assessment of the operation of sites and project's goals achieved that are discussed in the next Section.

IV. Final evaluation of the project's results in Poland

The evaluation of the project's results in Poland presented in this paper was based on the data gathered by the National Coordinator during the period of 2006-2010 when the project was carried out. Having selected and implemented the pilot sites, the evaluation process had a twofold character: on one hand it was performed as a project's internal workpackage, according to the same rules and criteria for all countries and regions.

The core of the corresponding evaluation methodology was provided by the Coordinator of the project and by the Consortium Partner responsible for the evaluation, while this methodology was continuously improved during the exchange of views at all Consortium meetings and the e-mail discussions afterwards. This part of the evaluation process was user-centered, based on the evaluation forms that had been sent to the end-users, filled-in at the training seminars and during other project's events, and were available on the web to be filled-in on-line.

Other streams of the monitoring and evaluation activities were linked to the technical aspects of the current operation of pilot sites, especially the users' feedbacks, have been analyzed by the National Coordinator's experts. The data on the transmission rates (down- and uplink) were continuously monitored and gathered for a later overall evaluation. Similarly, the information about the use of the terminals, such as the applications used, number and social structure of end-users, time at use, technical problems encountered, were gathered as well. The functionality of applications used and their responsiveness to the needs of different groups of end-users have been also evaluated.

While multicriteria outranking approaches based on weighting the individual criteria are commonly prevalent in deriving the rankings from individual scores, we have found out that a similarity measure to the ideal and satisfactory objects

TABLE II.
THE PILOT STATIONS OF THE 6TH FP RURAL WINGS PROJECT IN POLAND

ID	Place, host institution	Start of operation	Geographical situation	Description and type of the pilot site	No. of inhabitants / users	Goals to be achieved by this site and main target groups
POL 01	ZAWOJA, Babiogórski National Park	2007.03.28	longitude: 19°54, latitude: 49°65, altitude: 650 m asl	The pilot site is situated in the headquarters of the Babia Góra National Park (BGPN). close to Babia Góra (1725 m asl) Site type: Research Station & Wildlife Reservation	6200 / 2000	1. Supporting local administration in environmental issues 2. Better environmental education, enriching science learning and scientific activity in remote rural areas: high school and university students, teachers, 'green schools' participants 3. Using internet access for carrying out scientific research. Specific applications: producing and disseminating videos with observations of the Park's wildlife
POL 02	POLANA, Polana Private Salesian School	2007.03.29	longitude: 22°35, latitude: 49°18, altitude: 639 m asl	Polana is a small village in the south-eastern edge of Poland. It is situated in the central area of the Bieszczady Mountains. Site type: rural school	400 / 80	1. Using internet access for learning at school. 2. Using internet access for learning at home. Specific applications: local e-office access, WebTV - schoolchildren use cameras to record school events, then upload them to the web, e-learning applications supplementing the biology and English lessons
POL 03	WIŚNIOWA, The Private Adult Secondary School	2008.02.26	longitude: 20°12, latitude: 49°79, altitude: 380 m asl	The Wiśniowa Municipality is located in the mountains. 50 km to the south from Krakow It is surrounded by Site type: rural school	1900 /40	1. Using internet access for learning at school 2. Using internet access for learning at home Specific applications: UNITE platform -used during English lessons, and supplementing the biology and geography lessons
POL 04	MT. LUBOMIR, The Astronomical Observatory of the Jagiellonian University	2008.02.27	longitude: 20°08, latitude: 49°75, altitude: 904 m asl	Mt. Lubomir is situated in the north-eastern part of Beskid Makowski Mountains. The site is endowed with indoor WiFi for employees, and outdoor one for visitors. Site type: remote research station	1200 /100	1. Using internet access for carrying out scientific research. 2. Using internet access for learning. Specific applications: Discovery Space (D-Space) and similar applications allowing to transmit astronomical data from Lubomir via internet and to join the network of similar observatories. With D-Space the visitors of the Observatory are able to compare the views of astronomical objects from different telescopes
POL 05	ROKICINY PODHALAŃSKIE, Raba Wyżna Telecenter	2008.02.28	longitude: 19°91, latitude: 49°57, altitude: 550 m asl	Rokiciny Podhalańskie is a village in the Raba Wyżna municipality, about 70 km south from Krakow, in the Beskidy Mts. The pilot site serves the local telecenter. The outdoor WiFi, reaches the nearby recreational area. Site type: rural telecenter	Raba Wyżna Municipality: 13632, Rokiciny Podhalańskie: 1450 / 250	1. Intensive e-government-oriented training programs 2. The use of municipal web service of Raba Wyżna 3. Using internet access for learning at school 4. Using internet for learning at home and during leisure time 5. Using internet access for learning at work Specific applications: Electronic consultations on local community matters proposed by municipal authorities, WebTV - users record relevant events from the life of Raba Wyżna municipality, then upload it to the web.
POL 06	SKAWA, The Municipal Public Library	2008.02.29	longitude: 19°90, latitude: 49°62, altitude: 514 m asl	Skawa is a village in the Beskid Zachodni Mountains about 70 km south from Kraków. Site type: rural library	4000 / 300	1. Using internet access for learning at school 2. Using internet access for learning at home 3. Using internet access for learning at work Specific applications supplement the lectures on ecology and biology at the Library, and municipal web service of Raba Wyżna (e-govt)
POL 07	NOWY LUPKOW, Primary School	2008.11.06	longitude: 22°05, latitude: 49,15, altitude: 592 m asl	Nowy Łupków is situated in the Podkarpackie Voivodship, in the Bieszczady Mountains. Site type: rural school	390 /60	1. Better education: Enriching science learning and scientific activity in remote rural areas 2. Rural school teachers'training Specific applications: WebTV, schoolchildren record school events, then upload the movies to the web
POL 08	KĘTY, Secondary School No.9 in Kęty	2008.11.07	longitude: 19°90, latitude: 49°62, altitude: 514 m asl	The Community of Kęty is located in the Soła river valley, at the foot of the Beskidy mountains. Site type: county-level school	19500 / 300	1. Better education: Enriching science learning and scientific activity in remote rural areas 2. Rural school teachers' training Specific applications: Teachers` IT training seminars. Xplora, UNITE platform, Experinet have been used to enhance natural science lessons
POL 09	MYCZKOWCE Primary School	2009.02.06	longitude: 22°24, latitude: 49°26, altitude: 364 m asl	Myczkowce is a village in the Podkarpackie Voivodeship in south-eastern Poland. Site type: rural school.	510 /120	1. Better education: Enriching science learning and scientific activity in remote rural areas, 2. Rural school teacher training Specific applications: e-govt-oriented training, Cret@quarium, WebTV
POL 10	HARKABUZ, Primary School	2009.03.18	longitude: 19°50, latitude: 49°32, altitude: 809 m asl	Harkabuz is a village in the Raba Wyżna municipality, in the Beskid Zachodni Mountains. Site type: rural school	530 / 75	1. Better education: Enriching science learning and scientific activity in remote rural areas, 2. Rural school teacher training Specific applications: municipal web service of Raba Wyżna (e-govt), Cret@quarium, WebTV

Source: Progress & Business Foundation (2009)

defined at the selection phase would better correspond to the ideas underlying the functioning of pilot sites.

First, data characterizing the individual pilot stations' performance, containing 12 indicators, were gathered and indicators grouped into three groups: technical, intensity-of-use-related, and qualitative, Then the groups of criteria were aggregated to three synthetic objectives: those technical, based on transmission quality, those related to the intensity of use, and those describing the quality of fulfilling the Project's goals, based on interviews and qualitative assessments. The final ranking was derived by comparing the values of synthetic objectives with the corresponding values for reference sets containing the model and satisfactory objects.

The results of the *ex-post* evaluation, as of December 31, 2009, reported until March, 2010, are presented in Tab.4. For reference, in Cols. 9 and 10 we include a comparison with the results of *ex-ante* assessment and scenario expectations presented in Tabs. 1 and 3.

It is to be noted that, despite the deficiencies of the weighting methods, all technical criteria in Tab. 4 were aggregated based on an equal weighting. Thus the overall technical assessment criterion (col. 7 in Tab.4) was a result of rounding and normalising to the scale [0,…10] of the linear combination of the absolute transfer rates (positive weights) with the unreliability of the link expressed by the standard deviation of the down- and uplink rates (with negative weights).

Observe that the highest mean values received for downlink in the site POL05 were accompanied by highest connection risk that reduced the technical score. The main,

TABLE III.
A REVIEW OF PLANNED IMPLEMENTATION OF USERS' SCENARIOS IN POLISH PILOT SITES

No.	Scenario description	Satellite Internet Pilot Sites in Poland									
		POL 01	POL 02	POL 03	POL 04	POL 05	POL 06	POL 07	POL 08	POL 09	POL 10
1.	Entrepreneurship education: A rural e-shop run by students	N	P	P	N	P	P	N	XP	P	P
2.	Access to education: A virtual music school for rural students	N	P	XP	N	P	XP	N	P	P	P
3.	Students broadcasting local affairs through their own TV programme	XP	P	XP	XP	XP	XP	XP	XP	XP	XP
4.	Better education: Enriching science learning and scientific activity in remote rural areas	XP	P	XP	XP	XP	XP	XP	XP	XP	XP
5.	Rural school teacher training	P	XP	XP	XP	XP	XP	XP	XP	XP	XP
6.	On-the-field personalized communication and training services for farmers	P	P	P	N	XP	P	P	N	P	P
7.	Health emergency training	P	P	D	N	P	D	P	P	P	P
8.	Addressing change and innovation competences in rural communities	XP	P	P	XP	XP	P	XP	XP	P	P
9.	Individual learning (5 scenarios for different social groups)	XP	XP	P	P	XP	XP	P	P	P	P
10.	Improving internet access to public services and the electronic office (e-government)	P	P	P	P	XP	P	P	XP	P	XP
Overall *ex-ante* expectation of the dominant users' scenario		R	IAP	T-EL	R	E-G	IAP	T-EL	T-EL	T-EL	T-EL

The numbering of sites (POL01-POL10) in Tab. 3 is the same as in Tabs. 1 and 2. The other symbols used in Tab.3 are explained below:

XP - e**X**tensive use during the pilot phase highly **P**robable
P - **P**otential or Planned use at a later date
D - to be **D**etermined, depending on a possible expansion of the target group
N – **N**o use expected during the project's duration
E-G – Predominant use for **E**-**G**overnment
R -**R**esearch
IAP- **I**nternet **A**ccess **P**oint
T-EL- On site **T**eaching and **E**-**L**earning platform access

or for most sites even the only reasons of a lower-than-expected use of dedicated applications were lower-than-expected transmission rates, that made the use of some applications more difficult, and the initial lack of the most wanted e-government-oriented learning applications, tailored to Polish circumstances, that was supplied by the National Coordinator in the third year of the project.

Neither the National Coordinator nor the sites themselves had an influence on the technical criteria contained in cols. 3-6 in Tab. 4. The transmission rate values assumed in the project were 4 Mbaud for downlink and 2 Mbaud for uplink, so the values reached actually differ substantially from those initially assumed. Intensity of using Project's dedicated applications by all sites were measured by access time to the specific web pages and supplied by the project's partner responsible for these measurements. These data were normalised for all sites, taking into account the transmission rates at this site and the assumed number of potential users. It is to be noted that the ranking in Tab.4, should be regarded as touching upon only the aspects specified in this paper and it might not reflect the overall assessment of the sites' operation. Therefore the differences between the *ex-ante* (selection-stage) and *ex-post* evaluation ranks contained in col. 10 of Tab. 4 may serve exclusively as an illustration of the evaluation method and not as the final assessment. On the other hand, the values obtained show a good compliance between the expectations, that served as reference values, and actual results.

An additional aspect of the above evaluation resulting from the interdependence between the (*ex-ante*) needs analysis and *ex-post* evaluation of pilot sites, is to justify the rationale for the initial selection of sites. While the technical criteria of needs assessment and evaluation were different, the target goals, i.e. intensity of use, measured as the transmission volume, the average number of users per week and its stability, measured by the standard deviation of the above, as well as the second goal: filling-in the gaps in the broadband coverage, and the third-one: the number of users willing to use the dedicated applications made available within the project, could be compared as *ex-ante* expectations at the stage of selecting the pilot sites, and as *ex-post* evaluation results. To assess each individual site, its final outcomes were adjustted to the potential capacity of this site, rather than measured in absolute numbers. The difference between *ex-ante* expectations at the stage of selecting the pilot sites, and *ex-post* evaluation results, was taken into account, to measure the progress achieved. To assess the entire sites' selection process, the assessment of the overall benefits, resulting from the operation of all sites, can be taken into account as a separate criterion as well.

V. CONCLUSIONS

Based on the data gathered at the satellite internet pilot sites by the National Coordinator for Poland, and the studies carried out afterwards, we can conclude that the *'most probable'* Polish Information Society (IS) development scenario until 2025 and beyond contains a considerable use of satellite internet access in selected remote rural areas, where the duty of the dominating telecom operator to provide a broadband access to all citizens, that is imposed by law, can be

TABLE IV.
RESULTS OF EX-POST TECHNICAL EVALUATION OF THE RURAL WINGS PILOT SITES' OPERATION IN POLAND

No.	Site name and code	Mean down-link rate (kb)	Standard deviation of downlink (kb)	Mean uplink rate (kb)	Standard deviation of uplink (kb)	Overall technical assessment score [0…10]	Intensity of using dedicated applications	Deviation from ex-ante scenario assignment (Tab.2)	Difference between the ex-post and ex-ante ranks
1.	2	3	4	5	6	7	8	9	10
1.	ZAWOJA, POL01	1031,795	486,723	68,375	38,715	5	lower	none	0
2.	POLANA, POL02	902,946	538,364	N/A	N/A	4	lower	none	-1
3.	WIŚNIOWA, POL03	1133,273	508,9445	44,300	7,328	5	lower	none	-1
4.	MT. LUBOMIR, POL04	720,581	562,458	347,413	304,282	3	lower	later launch	0
5.	ROKICINY PODHALAŃS-KIE, POL05	1417,943	1525,783	58,661	49,041	5	standard	intensive e-govt	1
6.	SKAWA, POL06	1344,20	741,87	49,37	16,88	6	lower	none	0
7.	NOWY LUPKOW, POL07	1552,985	350,599	112,845	31,502	8	standard	none	1
8.	KĘTY, POL08	1323,77	665,22	88,01	47,22	7	higher	none	1
9.	MYCZKOWCE, POL09	823,546	467,881	58,091	71,147	4	lower	later launch	-1
10.	HARKABUZ, POL10	922,07	479,05	N/A	N/A	3	standard	later launch	0

fulfilled by the DVB-RCS or a similar bi-directional satellite technology in a most efficient and economical way.

The recommendations and conclusions resulting from the implementation and evaluation of the Rural Wings project in Poland, can be summarised as follows:

- The installation and operation of the satellite internet access points in the DVB-RCS technology overlaps with the middle-term Information Society (IS) policy goals, as specified in the related Polish IS policy documents, and with the statutory duties of dominating telecoms,
- With the forthcoming new generation of satellites, the DVB-RCS internet can provide safe and affordable e-infrastructure with geographically unlimited access,
- The successful operation of the D-Star terminal installations depends on the availability of comprehensible e-government, e-learning platforms, content and services,
- A growing role of e-health-related applications, that have to be made available to everyone, without geographical limits, is to be taken into account when designing the future deployment plans of the DVB-RCS technology,
- The satellite internet access can foster the extension of common intellectual sphere in the e-space and eliminate digital divide in rural areas;
- The development of local information societies in rural areas based on the satellite DVB-RCS technologies will support a move from the traditional agriculture to the development of future innovative, sustainable, environment-friendly agriculture that supplies high-quality end products and uses sophisticated IT, such as robotics, monitoring and control. Similarly, other branches of rural economy, such as tourism, specifically agrotourism, will benefit from the satellite broadband access.

Furthermore, the conclusions resulting from the *ex-post* evaluation of the initial ranking procedure give an insight on the overall evaluation methodology for the satellite internet access points. The *ex-post* evaluation of the initial ranking, based on the comparison of initial ranking and the *ex-post* assessment criteria studied in Sec.IV, may allow to derive a learning scheme, which – in turn – can be useful to assess the adequacy of the selection criteria, the adequacy of choice and correctness of using of the multicriteria outranking procedure applied in the selection process and the credibility of data supplied by the applicants. To make such a comparison possible, the actually observed criteria need to be transformed to the measures of the above goals, taking into account the uncertain character of the initial expectations. The evaluation process of the functioning of ten DVB-RCS pilot sites in Poland allows to derive a subset of relevant needs assessment criteria from a larger set of criteria considered at the site selection phase.

A similar approach to the presented above can also be applied to assess the adequacy of the multicriteria decision-making method applied to derive the final (*ex-post*) pilot sites' ranking. The core of the procedure consists in calculating the distance between the initial and final rankings, which reflects the efforts that would be needed to get the results anticipated, as seen *ex-post*. An aggregated value function, describing the quality of assessment and quality of performance of selected sites can be defined as well. In case of repeated decision problems, its outcomes can be used as inputs for a learning scheme. This approach is universal in the sense that it can be applied to any similar problems, involving an initial ranking, and the performance of N selected objects based on this ranking. Specifically, a general methodological framework to select satellite internet access points could be based on the scheme here proposed.

Finally, let us mention that based on the economic forecasts and scenarios for Poland [6], the infrastructural IT satiation in Poland will come between 2014 and 2017 [7], to-

gether with the development of commonly accessible e-economy, e-government, e-health, and e-learning applications [8]. This breakthrough will set the high-quality broadband access and common IT literacy among citizens to one of the top policy priorities.

To sum up, there is a considerable potential for satellite-based e-government, e-learning and e-health in Poland, the latter especially for preventive medicine and m-health applications [4]. One can expect that m-health in remote and sparsely populated areas shall be based on the satellite internet, which is regarded as more reliable that the wireless-ground-based connections. It is also worth to mention that e-learning, e-government and e-health-related actions, activities and public funding have been included in the strategic local policy documents in Polish regions concerned, i.e. in Małopolska and Podkarpackie Voivodships, which makes future implementations plans, resulting from the Rural Wings project feasible.

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