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High Capacity Ethernet Radio Relay Networks in Mobile Communications

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Abstract

The present paper studies the main characteristics of digital radio relays used by the largest mobile network operator (MNO) in Romania in order to develop a network supporting the newest technologies available on the market. The main contribution is the design of a high capacity Ethernet radio relay network in an area around Bucharest, Romania. The location was chosen on the criterion that it is a high-density traffic area where high-capacity radio links are in operation and use the newest digital radio relay features that are explained in this paper: high modulation scheme, adaptive radio modulation, radio traffic aggregation and cross-polarization interference cancellation. The network contains PDH and SDH links to transport the entire traffic in the area. We analyse several links between different sites that present particularities in the mobile operator's network. Finally, the most suitable parameters are chosen and the designed radio relay network is presented and analysed. It has been implemented in the MNO's network since 2015.

Keywords: Radio Relay, Microwave, AMR, XPIC, RTA, LoS, Traffic, Mobile Network, Capacity, Antenna, ODU, IDU

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1. Introduction

Microwave systems have been in service for many years in networks that are flexible, of high quality and cost efficient. Over the years, these systems have evolved with respect to the supported capacity and features, so that today they can support all types of fixed and mobile voice applications, data and transport protocols. Today, most of the mobile sites in the world are connected to the access domain by digital point-to-point radio systems.

Microwave links have lower implementation costs than fibre optic ones, can be installed very quickly and in hardly accessible areas. Sometimes they are used as backup for fibre, because they are more resilient to earthquakes, landslides and other natural phenomena.

Moreover, fibre is not as flexible as point-to-point radio links when it comes to planning. It is not infrequent for operators to change the site locations and, thus, the fibre link has to be routed to the new locations, which means additional costs and more time consumed. Radio links can be easily reconfigured with small costs and in a short time.

The radio link studied in this paper is a point-to-point digital link that operates in frequency division duplex (FDD) mode. The operation of duplexing mean that each radio frequency (RF) channel consists in one pair of frequency for transmission and one for reception[1]. The radio relays used to design the network presented in this paper support both PDH and transport over radio packet data (Ethernet) technologies and they employ special features such as Adaptive Modulation Radio (AMR), Cross-Polarization Interference Cancellation (XPIC), Radio Traffic Aggregation (RTA) or Multiservice Aggregation (MTA).

The paper is organized as follows: Section 2 presents the steps to design and plan a high capacity Ethernet radio-relay network in a city in Romania: Subsection 2.1 presents the link budget of a radio link that consist in choosing the capacity , the frequency and the configuration of the path, Subsection 2.2 presents link calculation between two sites representing a special path because of the high capacity (916 Mbps) and the necessary configuration to hold this capacity. Results are shown and discussed in Section 3 and, finally, Section 4 draws the conclusions.

2. Measurement setup

This section presents the steps to design and plan a high capacity Ethernet radio-relay network in a city in Romania, by a local mobile network operator. The location was chosen on the criterion that it is a high-density traffic area where high-capacity (max. 916 Mbps) radio links are in operation and use the newest digital radio relay features: high-order modulation (max. 1024-QAM), XPIC, AMR and RTA.

In order to implement the network, MPR Ethernet radio-relays were used and digital radio-relays manufactured by NEC: iPaso and standard NEC. The software application that enables the design of the network is NETCOP and is manufactured by ESG GmbH Germany.

Sites in the city have been indexed from SITE A to SITE U. The sites that are used for leased-lines for the private services offered to clients are termed Point of Interconnect (POI), numbered 1-10. Sites A, B, C are backbone sites because they are linked to the national optic fibre network. They aggregate the entire traffic from the city and transport it through the optic fibre network to the central point. Other important transmission nodes are SITE D, SITE I and SITE E that each take a large part of the traffic in the area. In the city, most of the sites generate traffic from the BTS, NodeB, eNodeB and WiMAX equipment. Fig.1 shows equipment used in each site and total traffic generated by these.

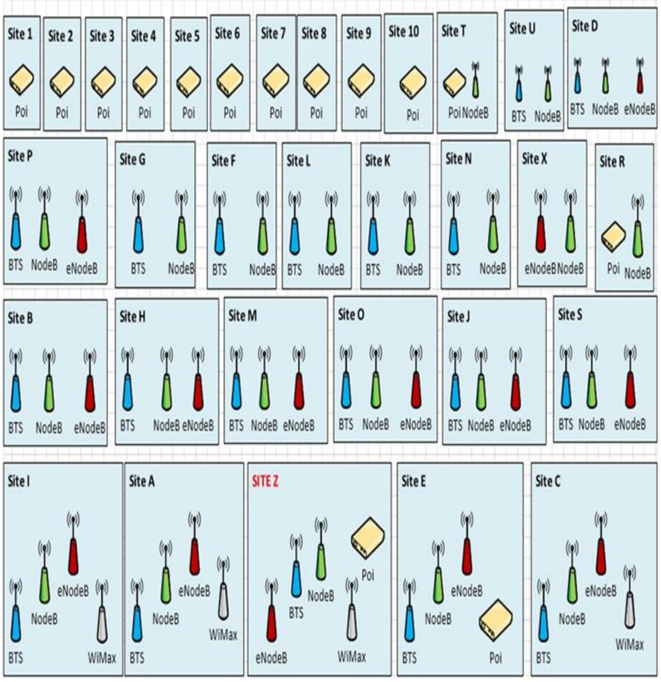


Figure 1. The equipment used and traffic generated on each site

2.1.Link Budget

On average, there are two Base Transceiver Station (BTS) cabinets in the Orange site (one for the 900 MHz band, and the other for the 1800 MHz band). Each cabinet has two E1 ports for voice and data traffic. In total we need a 4E1 transport capacity (meaning approx. 8 Mbps). After some simple internal calculations, the operator comes to the conclusion that the necessary capacity for dedicated data subscriber access varies from site to site, according to their requirements, ranging from 256 kbps to 350 Mbps.

As noticed in Table 2 and 3, A-B, B-C and A-C are SDH radio links which comply with the same propagation principles as other radio links, the only difference being that the traffic type is optical with a capacity of 1 STM1, meaning 155 Mbps. They are designed this way because they aggregate an important amount of traffic which is carried directly into the main optic fibre network core, where the traffic can be carried over two routes: main and spare. Next, starting from the previous data, the radio link budget has to be determined. The budget will take into account the necessary link capacity, equipment capacity and maximum coverage at a certain operating frequency.
Therefore, choice of transmit frequency is done according to the radio link distance. For example, for a Line of Sight (LoS) distance of 2 km, ODUs in the 38 GHz frequency band will be used and for a LoS distance of 15 km, ODUs in the 15 GHz frequency band will be used. In Table 1 we can observe the dependencies between frequencies (used in our network) and distance. Each site has its GPS coordinates in the NETCOP software, and whether or not there is LoS between two sites is determined based on these coordinated. All the links in the designed network have LoS between them. This is reassured by going into the field and doing a site survey at each of the sites to check LoS.

Table 1. Dependencies between frequencies and distance

Frequency [GHz]	Colour	Distance [km]
38	blue	3
25	yellow	4/5
23	Red cherry	6/7
18	violet	10-15
15	green	15-20
13	black	35-45
6.7	cyan	45

We can use multiples configurations of radio links. The most used configuration is 1+0 and it is formed by one antenna, one ODU and one IDU in both parts (transmission and reception) using the same polarization as we can see in Fig. 2 [2].

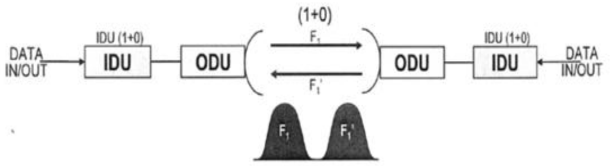


Figure 2. Radio link in 1+0 configuration

We also used in our network the 2+0 configuration with XPIC that is formed by two parallel links that used 1+0 configuration, but with a common IDU. That configuration need one IDU, two ODUs and a dual-pol antenna on both sides. For the transmissions we used the same radio channel F1 but in different polarizations: the F1 channel transmits data on a direction polarized vertical and in parallel it transmits data on another direction polarized horizontally. OMT (Orthogonal Mode Transductor) separates horizontal polarization from the vertical polarization. On the IDU arrive data on F1(V) and F1(H) , but with the help of XIF cable it make the difference between data: in the direction of the ODU polarized vertically it received F1(V) like helpful signal and F1(H) like perturbation and it is eliminated. The same thing happens on the direction of the ODU polarized horizontally [2]. The main advantages of this configuration are that we can transmit big capacities over the air and we can save radio spectrum because the transmissions on the both sides are made on the same channel.

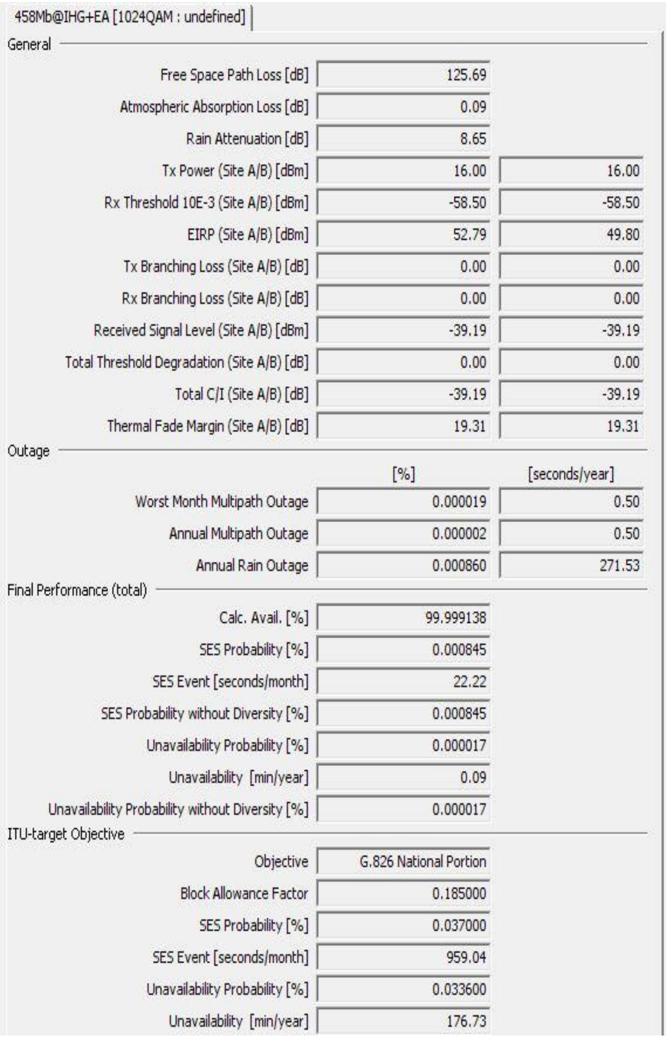
2.2. Link designed between Site E and Site Z

Let’s consider, for example, the E-Z link, which has greater interest because of the high capacity (916 Mbps) and the necessary configuration to hold this capacity. This capacity can be assured by using iPasolink equipment with a 2+0 configuration with XPIC using 1024-QAM modulation and RTA techniques.

First of all, the existence of LoS is checked using NETCOP with the initial design data. We find that there is LoS between the two sites. Also, we obtain that the radio link distance is 3.812 km. This means that we could use transmit frequencies of 25 or 23 GHz to ensure optimum transmission. However, we must also take into account another aspect in choosing the transmit frequency: radio spectrum availability in the link sites. We can see in Fig.4 that in site E there is a radio link in the 15 GHz band, and one in the 25 GHz band, so, we could use 23 or 25 GHz. The problem remains in site Z, because this aggregates several links in the 23 and 25 GHz band so that means it is next to impossible to find an available frequency with 56 MHz channel spacing (these links cannot be seen in Fig.4 because they belong to another area in the city; we still have to take these into account when designing new radio links in the border area, because site Z is at the border of two large areas in the city).

Taking into account all that was previously mentioned, we will use the 18 GHz frequency for the radio link. Usually this frequency is used for links with a distance of 10-15 km and antennas with a higher radius are used (usually 0.6-1.2 m in diameter). This doesn’t mean they cannot be used for a smaller distance like in our case.

In order to find the optimum antenna, the radio link budget for the SITE E – SITE Z radio relay was calculated, taking into account different possible antenna radii. First, we choose antenna with a diameter of 0.3 m at both ends and we obtain the radio link budget parameters generated by the Netcop report. We obtain that the Received Signal Level (RSL) is -45.46 dB and there is a link availability of 99.998 when there is a TX power of 16 dB. The signal level is not enough (the optimum level agreed in the mobile operator’s network is -39 dB) and the link availability is not acceptable, so these aspects can be further enhanced. Next, we will try an antenna with a radius of 0.6 m in site E, and one with a radius of 0.3 m in site Z. Modifying the antenna diameters is the only option to enhance radio link performance, because only a channel spacing of 56 MHz and 1024-QAM modulation can be used for ensuring this great capacity.



458Mb@IHG+EA [1024QAM : undefined]

General		
Free Space Path Loss [dB]	125.69	
Atmospheric Absorption Loss [dB]	0.09	
Rain Attenuation [dB]	8.65	
Tx Power (Site A/B) [dBm]	16.00	16.00
Rx Threshold 10E-3 (Site A/B) [dBm]	-58.50	-58.50
EIRP (Site A/B) [dBm]	52.79	49.80
Tx Branching Loss (Site A/B) [dB]	0.00	0.00
Rx Branching Loss (Site A/B) [dB]	0.00	0.00
Received Signal Level (Site A/B) [dBm]	-39.19	-39.19
Total Threshold Degradation (Site A/B) [dB]	0.00	0.00
Total C/I (Site A/B) [dB]	-39.19	-39.19
Thermal Fade Margin (Site A/B) [dB]	19.31	19.31
Outage		
	[%]	[seconds/year]
Worst Month Multipath Outage	0.000019	0.50
Annual Multipath Outage	0.000002	0.50
Annual Rain Outage	0.000860	271.53
Final Performance (total)		
Calc. Avail. [%]	99.999138	
SES Probability [%]	0.000845	
SES Event [seconds/month]	22.22	
SES Probability without Diversity [%]	0.000845	
Unavailability Probability [%]	0.000017	
Unavailability [min/year]	0.09	
Unavailability Probability without Diversity [%]	0.000017	
ITU-target Objective		
Objective	G.826 National Portion	
Block Allowance Factor	0.185000	
SES Probability [%]	0.037000	
SES Event [seconds/month]	959.04	
Unavailability Probability [%]	0.033600	
Unavailability [min/year]	176.73	

Figure 3. The report generated by Netcop at the design of link E-Z with with one 0.3 m diameters antenna and one 0.6 m diameters antenna

With 0.6 m diameter antenna in site E (Fig.3) we obtained a RSL improvement of over 5dB (RSL= -39.19 dB) and the radio link availability rises to 99.999138 (meaning that 0.09 min/year the link is unavailable). These results are deemed acceptable by the mobile operator's standards and the link can be implemented using these parameters.

3 Results

Fig.4 shows the designed radio relay network for the considered city. Sites are geographically positioned, according to GPS coordinates. The sites are linked for transport according to LoS existence or non-existence. Site B and Site D aggregate the most links because of the high probability of LoS.

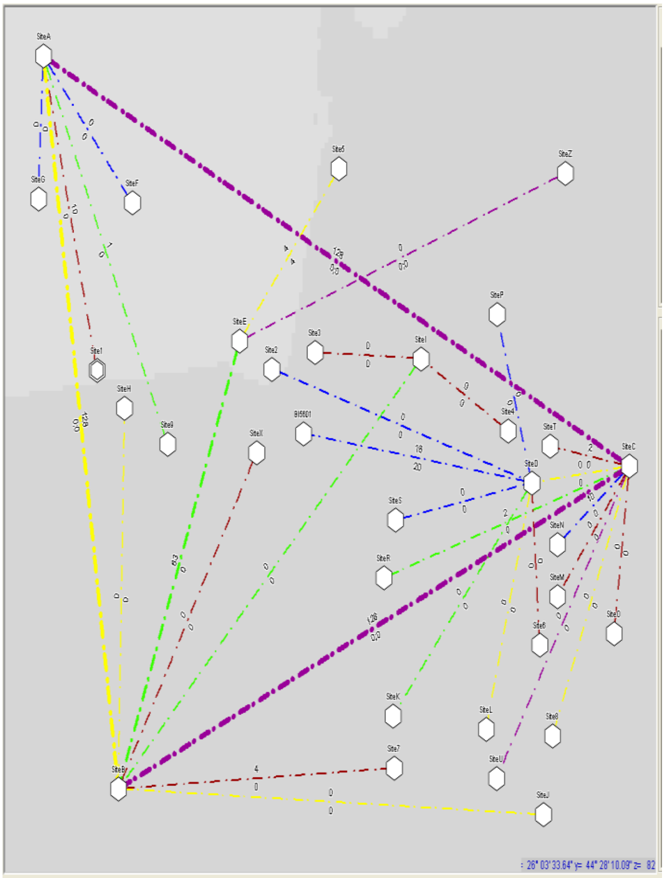


Figure 4. The projected radio Ethernet relay network in Netcop

Colour code used to display radio links is according to Table 1. We can thus notice that radio relays are used with transmit frequencies of 38, 25, 23, 18, 15 GHz.

The same way as for the E-Z link we computed the radio link budget for all LoS links necessary to aggregate traffic from sites to the core network for the city. Radio link performance parameters for the radio relays are given in two tables. Table 2 shows radio parameters that need to be configured for equipment as well as the length of the antennae necessary for obtaining parameters in Table 3.

4 Conclusions

This paper presented the steps of the projection of a radio Ethernet relay network that used big capacities and it is functional in present in the network of a mobile operator from Romania. We made the link budget for every path between the sites of the city taking in account the initial data of projection, that include the type of generated traffic by each site on this area and the capacity required to transport this traffic. We analysed, particularly, the link between sites that present some singular particularities in our network: it is in 2+0 configuration with XPIC, uses radio techniques like RTA, AMR and offers, in present, in the mobile operator network, the largest capacity provided on the radio environment: 916 Mbps.

Taking into account the aspects presented in this paper, we think that the microwave links represents an efficient and flexible solution for the development of one telecommunications network (especially on access part) that can hold all the types of services: voice, data and fixed services from second, third or four generation.

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[3] Alcatel Lucent training radio, Orange Romania 2013
[4] ITU-T Recommendation G.811, Timing characteristics of primary reference clocks

Table 2. Radio parameters of the links projected , part I

		SITE A				SITE B			
Site A	**Site B**	Frequency (MHz)	Attenuation (dB)	Antenna Diameter (cm)	Azimuth (deg)	Frequency (MHz)	Attenuation (dB)	Antenna diameter (cm)	Azimuth (deg)
A	B	25571	0	60	170.23	24563	0	60	350.24
A	C	19480	0	60	113.61608	18470	0	60	293.65118
B	C	18360	0	120	247.30148	19370	0	60	67.27121
A	G	37765	15	30	210.2524	39025	15	30	30.24978
A	F	39032	10	30	316.21	37772	10	30	136.2
A	1	23299.5	10	30	344.5301	22291.5	10	30	164.52677
B	H	25571	0	60	170.23	24563	0	60	350.24
B	E	14725	2	30	208.89865	15215	2	30	28.89026
B	X	23282	0	60	97.75772	22274	0	30	277.79098
B	7	23556	6	30	234.56	22302	6	30	215.29998
B	J	25571	3	30	154.67	24563	0	30	267.45
E	5	25599	14	30	5.62	25599	14	30	5.62
E	Z	19370	0	60	72.37	18360	0	30	252.4
I	3	22127	0	30	211.25845	23135	0	30	31.23901
I	4	22141	4	20	104.31	23149	4	20	284.31
D	2	37800	5	30	277.77	39060	5	30	97.75
D	S	39021.5	8	30	84.98	37761.5	8	30	264.99
D	K	18346.25	0	30	31.27	19356.25	0	30	211.28
D	L	24619	20	30	234.44764	25627	20	30	54.4447
D	P	37800	8	30	52.87	39060	8	30	232.88
D	6	23306.5	10	30	273.84758	22298.5	10	30	93.83864
C	D	24622.5	0	30	126.42	25630.5	0	30	306.44
C	T	22134	9	30	187.4618	23142	9	30	7.46096
C	R	15215	0	60	134.41441	14725	0	60	314.46647
C	N	37772	2	30	168.73562	39032	2	30	348.738
C	M	23149	2	30	240.24073	22141	2	30	60.22317
C	U	18442.5	7	30	206.4096	19452.5	7	30	26.40731

Table 3. Radio parameters of the links projected, part II

Site A	**Site B**	**Capacity (Mbps)**	**Model**	**Frequency (GHz)**	**Modulation Scheme**	**Polarization**	**TFM (dB)**	**Availability (%)**	**RSL (dB)**
A	B	2*STM1	SDH	25	128QAM	VH(2+0)	23.469	99.999	-38.9723
A	C	2*STM1	SDH	18	128QAM	VH(2+0)	22.344	99.998	-39.1995
B	C	2*STM1	SDH	18	128QAM	VH(2+0)	34.850	99.999	-39.467
A	G	64.8	MPR	38	64QAM	H	34.005	99.997	-39.321
A	F	111.36	MPR	38	32QAM	V	35.950	99.999	-37.452
A	1	20	NEC	23	4QAM	V	49.204	99.999	-39.513
B	H	111.36	MPR	25	32QAM	H	22.271	99.996	-37.467
B	E	182.3	IPASO	15	256QAM	V	33.678	99.997	-38.678
B	X	182.3	IPASO	23	256QAM	V	29.456	99.999	-39.045
B	7	40	NEC	23	16QAM	H	22.215	99.996	-39.456
B	J	136.6	IPASO	25	64QAM	V	35.839	99.999	-40.023
E	5	20	NEC	25	16QAM	V	35.0388	99.997	-38.980
E	**Z**	916 (2+0) 458*2	IPASO	18	1024QAM	VH(2+0)	29.78	99.988	-39.66
I	3	80	NEC	23	32QAM	V	32.660	99.995	-38.543
I	4	40	NEC	23	16QAM	H	22.215	99.998	-39.238
D	2	20	NEC	38	16QAM	V	44.751	99.9996	-39.956
D	S	65.28	MPR	38	64QAM	V	34.1762	99.999	-39.494
D	K	136.6	IPASO	15	64QAM	V	32.205	99.997	-39.848
D	L	111.36	MPR	25	32QAM	V	34.099	99.989	-39.678
D	P	87.04	MPR	38	16QAM	H	31.39	99.998	-40.004
D	6	40	NEC	23	16QAM	H	32.077	99.999	-39.786
C	D	320.1	IPASO	25	128QAM	V	34.782	99.999	-39.658
C	T	40	NEC	23	16QAM	H	33.675	99.995	-40.023
C	R	20	NEC	15	4QAM	V	37.65	99.998	-39.345
C	N	67.7	IPASO	38	64QAM	V	31.554	99.999	-38.665
C	M	111.36	MPR	23	32QAM	V	5.8016	99.997	-39.856
C	U	111.36	MPR	18	32QAM	H	5.4973	99.997	-39.496