Wireless Backhaul Architecture for Small Cells Deployment exploiting Q-band Frequencies

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Abstract: The demand of capacity in mobile communication is growing exponentially day-by-day, as the numbers of users have been increasing drastically. LTE and small cell network topologies are being hailed as the solution to this; however, the backhaul has become the real challenge. Operators have typically used different backhaul technologies for their radio access networks. Nevertheless, existing alternatives such as fibre, Digital Subscriber Line (DSL), and microwave backhaul do not provide the required CAPEX, OPEX and/or performance to meet these requirements. The SARABAND project is proposing an architecture providing multi-gigabit capacity in a cost effective manner by exploiting point to multipoint links and the Q-band spectrum. This solution provides huge advantages in CAPEX for access capillarity (last mile) when compared to FTTH and in OPEX for backhaul when compared to microwave links. This paper defines the Q-band point-to-multipoint architecture as well as the key type of nodes comprising the SARABAND architecture. Multi-beam antennas and radio parameters will also be determined to deliver segmented coverage areas and the expected capacity on each segment of the network. Finally, a techno-economic study comparing the proposed solution versus traditional point-to-point microwave backhaul will be presented.

Keywords: Wireless backhaul, small cells, LTE, Q-band spectrum.

1. Introduction

Consumer demand for mobile broadband services is continually increasing, requiring operators to provide more and more capacity from their radio access networks. Actually, CISCO's top line global mobile data traffic growth projects show mobile data traffic increasing 26 fold from 2010 to 2015 [1]. Mobile Insights Europe, in an April 2010 report, projected traffic growth by a factor of 30 versus an 84% increase in revenue [2].

Looking at these figures, Mobile Network Operators (MNOs) need to find ways to meet that demand in a cost effective manner, and are increasingly looking to LTE as the answer. Despite the introduction of advanced 4G/LTE mobile technologies into their networks, operators' forecasts show that additional steps are required to enhance capacity and maintain current quality of experience levels. As a result, operators have begun to introduce small cells into their networks in order to keep up with consumer demand [3].

Deploying large numbers of small cells helps solve the capacity problem for the radio access network, but adds a novel challenge for small cell backhaul. Additionally, LTE provides reasonably fast access speeds, but if the pipes behind the LTE base station are too

narrow, then all the benefits go out the window. Therefore, an adequate backhaul upgrade is needed in order to provide the required capacity. But backhaul can be expensive in terms of both CAPEX and OPEX and operators are more and more TCO (total cost of ownership) focused. None of the traditional solutions provides the necessary combination of capacity and cost-efficiency.

This paper defines the architecture for future mobile backhaul and access wireless networks as proposed in the framework of SARABAND project. This architecture is based on a new multiplexing technology that allows the aggregation of multiple independent channels (modems) through wideband radios and antennas onto a single air interface. This solution offers an all IP point to multipoint (PMP) architecture providing multi-gigabit throughput to multiple base stations in a single sector. The use of millimetre wave technology, concretely the use of Q-band spectrum (40,5 – 43,5 GHz), provides the required amount of spectral bandwidth needed for the aggregation of sub-channels to the wide radios and antennas. The combination of wide spectrum and PMP has huge advantages: in CAPEX for access capillarity (last mile) when compared to FTTH and in OPEX for backhaul when compared to microwave links. Therefore, the proposed architecture offers a cost effective alternative to fibre for boosting network capacity and offering high speed broadband multimedia services.

Apart from the network definition, the key type of nodes comprising the SARABAND architecture (transmission hub and network terminal equipment) will be described and their physical parameters will be specified. Multi-beam antennas and radio parameters will be also determined to ensure the segmented coverage and the expected capacity and throughput on each segment of the network. These requirements will take into account all constraints such as LOS coverage limitations, rain and snow impact on range availability. Finally, to appreciate the real impact of the proposed PMP solution, a techno-economic study comparing PMP versus microwave links will be addressed.

2. Market problem and operators' requirements

Demand for bandwidth is growing exponentially as consumers use their mobile devices increasingly with more bandwidth-intensive applications and therefore the demands on the 3G+/4G networks increases at the same exponential rate. Actually, as the average consumption of mobile data increases from circa 1-2 Gbps per month to the level of fixed broadband consumption of circa 10-20 Gbps per month, the backhaul requirements are becoming increasingly expensive for MNOs to manage. These growing levels of consumption have a knock-on effect on the typical requirements for an MNO cell site, which has risen from circa 2 Mbps for a 3G site to circa 100 Mbps for an LTE site. As an example, the Figures 1.a to 1.c show the number of cell sites of a leading European operator in 2010 in a urban area, the recent and forecasted site growth, in line with the capacity requirement per km^2.
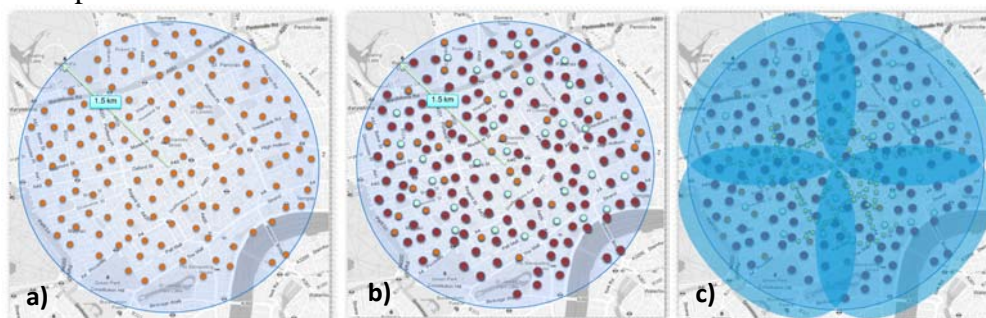

Figure 1. Recent and forecasted cell site growth

Figure 1.a shows the existing 3G sites in a urban area in 2010. In that time frame we see that 3G sites were already dense with 200-300 metre range between sites, resulting in a 10-Mbps per site and 200-Mbps capacity per km^2 requirements. In the meantime, the operators started using Carrier Wi-Fi to offload (de-saturate) 3G networks so that 20% of the data traffic is typically carried on Wi-Fi [4]. The new Wi-Fi site requirement is 10 Mbps and the incremental per km^2 requirement is at 50 Mbps capacity. In Figure 1.b, we see that operators are deploying 4G LTE cells, from 2013 onwards, to boost capacity. Some existing 3G sites will be upgraded to LTE, and some will remain on 3G initially, requiring now 35 Mbps (conservative value) per site and an additional 500 Mbps capacity per km^2.

The Small Cell mass deployment is expected by 2014 with 100-200 metre cell ranges and street level hot spot deployments, requiring 20 Mbps (conservative value) per site and another 250 Mbps incremental capacity per km^2, being now the total capacity requirement per km^2 of 1 Gbps. Then, to tackle this challenge, scalable, multi-gigabit Het-Net backhaul system for 3G, 4G, Wi-Fi and Small Cells is required. With the standard SARABAND solution, operators can create 4 sectors of coverage with a range of up to 2 km, generating up to 10 Gbps of capacity in one polarisation, as shown in Figure 1.c. This capacity can be scaled and increased with the introduction of multi-beam antennas deploying smaller coverage and capacity per km^2 segment. Therefore, providing Gigabit capacity per square kilometre is key to meet future demands and the goal is to find a backhaul solution that offers that capacity as well as flexibility to provisioning services, small footprints, easy installation, a cost-effective price structure, seamless support of IP/Ethernet and without compromising the quality of service.

Fibre, copper and microwave will cover some of this but the majority of sites will need a new backhaul system that provides scalable capacity for unplanned explosive growth at a TCO that meets the operators' business model. Actually, fibre provides a very high-capacity and low-latency connection, however it is neither fast to install nor cheap to do so. Digital Subscriber Line (DSL) can provide a basic level of connectivity; however, it will not provide the peaks needed for a good end user quality of experience. On the other hand, Non-line of sight (NLoS) wireless solutions might seem like a great way to reach the new outdoor small cells, but there is a distinct lack of suitable spectrum at low enough frequencies to deliver sufficient capacity. Traditional point to point (PTP) microwave backhaul requires two radio-antennas for every link, resulting in heavy OPEX (rent of sites and frequencies) and too expensive for the continuously evolving small cell deployment. Multipoint microwave occupies the ideal middle-ground between these extremes, having enough capacity to backhaul tens of small cells, and a much lower TCO and speed-to-deploy than a PTP solution. Multipoint microwave will be thus an essential component in an operator's toolbox of small cell backhaul solutions. However, traditional PMP, such as the ones operating in the 20 GHz bands offer some potential CAPEX/OPEX efficiencies, but unfortunately, do not have the required capacity to meet future market needs in terms of bandwidth. Therefore, the issue then for MNOs is this: how can they backhaul small-cell LTE in an affordable way, without sacrificing capacity?

3. Millimetre-wave Point to Multipoint Solution

Point to point microwave radio links are a well-established and mature technology that has been applied often to backhaul mobile traffic. In a PTP architecture *n* endpoints require *n* times dedicated PTP links, resulting in innately equipment-heavy and expensive (TCO) network. Unlike the PTP solution, PMP systems are inherently characterized by the ability for a single radio or hub terminal to sustain links with multiple remote terminals. This ability to support *n* radio links with only *(n+1)* radios is PMP's fundamental advantage over PTP systems, which means a significant decrease in CAPEX but an even more

dramatic cut in OPEX, since the number of antennas (and therefore site rental charges as well as frequencies acquisition) lessens and the tower is less encumbered.

However, although PMP microwave improves the resource utilization, microwave technology is not suitable for providing the required bandwidth demand of the next generation of wireless networks. At this point, millimetre-wave (mm-wave) band, especially in the Q-band (40,5 – 43,5 GHz), is very promising for high data rate mobile applications because of its large amount of spectral bandwidth available suitable for wide channels [5]. Namely, Q-band offers 3GHz bandwidth, 6GHz with cross-polarization. This wide bandwidth also enables the capability to scale the capacity of wireless links as demanded by market needs. Other advantages of Q-band over higher frequencies such as U- or E-band are its better coverage compared with U-band, its better link budget compared with E-band (less atmospheric and rain attenuation, better noise figure and power), its large business opportunities as CEPT decision and ETSI normalization makes easy acceptance for operators and many countries out of Europe follows and lower fabrication costs than higher frequencies.

Moreover, mm-wave point to point solution (in Q-band) provides a flexible network topology, adaptive throughput rate, simple and cost effective last mile distribution from fibre optics points, low radiation levels as well as compact and light equipment and ease of interference-free system configurations.

Given all these benefits, SARABAND project has considered this solution as the most beneficial for the implementation of next generation wireless backhaul networks. Actually, the proposed wide-band PMP system leveraging Q-band frequencies can aggregate traffic to better using high capacity backhaul fibre, essentially extending its reach. Moreover, the system equipment uses a 1 GHz wide transmitter that can be loaded with 25 channels (nominally 40 MHz wide) to create the bandwidth required only using the bandwidth provisioned. A base station can be configured to use as little as 40 MHz or all 3 GHz (@ 40 GHz using 3 transmitters fully loaded) so that the more spectrum that is available the more bandwidth can be delivered on a point to multipoint sector to facilitate Nx100 Mbps services. Therefore, this solution can backhaul small-cell LTE in an affordable way while fulfilling the capacity requirements and all the operators' requirements described in the previous section.

4. SARABAND network architecture

4.1. Network scenarios

SARABAND solution operates at millimetre-wave frequency bands, which offer larger channel allocation. At these frequency bands the service area is divided in small cells or sectors (pico-sectors or pico-cells) which allow efficient frequency reuse plans with very high frequency repetition rate. But depending on required bandwidth, the appropriate cell size and number of base stations per sector should be defined. Actually, there are several questions to be addressed:
- What is the area to be covered by a backhaul wireless point to multi point?
- What will be the cell density?
- Finally how many base stations are to be connected by a backhaul sector?

Depending on the throughput and on the link budget (e.g. high gain antennas, 30 mm rain density, 99.99% availability), the maximum range of radio transmissions in Q-band is up to 1 km in a PMP solution with sector antennas. Fibre optics PoP can be accessible every 1.5 Km. Thus the range of the system should be of 1 km. This is coherent with the operator's forecast on the proportion of fibre and wireless backhaul: 20% fibre and 80% microwave. The cell diameter varies today from 300 m to 1 km, being less than 300 m in

the centre of large metropolis with a high density. Thus within a km, in a sector of 90° the number of base station to backhaul will start from 5 up to 20. The capacity in such a sector will grow up to 150 Mbps x 20 that means 3 Gbps. With increasing of density and coverage range the number of base stations connected may grow up to 20 in a sector (sector beam width: 90° and 45°).

Taking into account these numbers, several scenarios with decreasing cell radius (from 200 m to 140 m) have been studied in order to verify if standards network elements can fulfil the required capacity for small deployment (Figure 2):

- Scenario 1: "Small" Cells of 200 m: 7 Base Stations per Sector (28 with 4 sectors). In this first scenario, level 1 and 2 base stations will be connected and some well-located base stations of level 3.
- Scenario 2: "Small" Cells of 160 m: 10 Base Stations per Sector (40 with 4 sectors). In this second scenario, level 1, 2 and 3 base stations will be connected
- Scenario 3: "Small" Cells of 140 m: 13 Base Stations per Sector (50 with 4 sectors). In this second scenario, level 1, 2 and 3 base stations will be connected plus some level 4 in visibility.
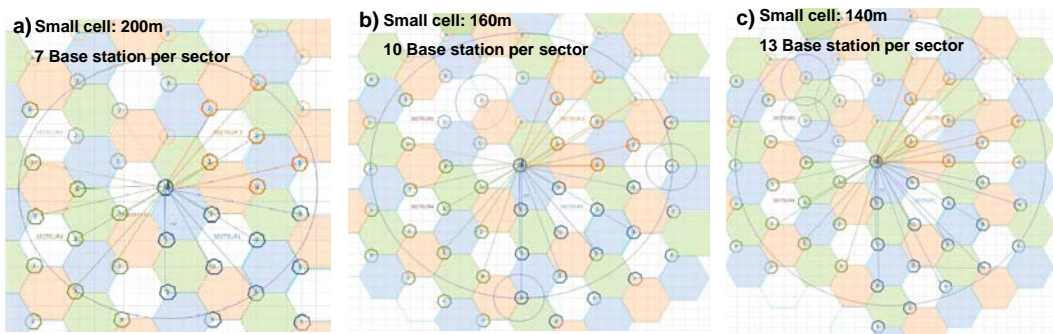
Figure 2. Small cells of; a) 200 m; b) 160 m; c) 140 m

In these three scenarios, the backhaul capabilities considering standard reference antennas have been obtained. Table 1 summarizes the obtained backhaul capabilities.

cell radius m	BS/ sector 90°	actual capacity Mbps	step 1 capacity Mbps	step 2 capacity Mbps	BS/ sector 90°	actual capacity Mbps	step 1 capacity Mbps	step 2 capacity Mbps
	1sector	16QAM	64QAM	2*16QAM	2 sectors			
200	7	578	630	840	14	1156	1260	1680
160	10	770	900	1200	20	1540	1800	2400
140	13	910	1170	1410	26	1820	2340	2820
	3 sectors				4 sectors			
200	21	1734	1890	2520	28	2312	2520	3360
160	30	2310	2700	3600	40	3080	3600	4800
140	39	2730	3510	4230	52	3640	4680	5640

Table 1. Capacity as a function of the number of base stations per sector and cell radius

The simulation results clearly show that the future throughput cannot be met with standard antennas and radio modules. To solve this problem, some improvement in terms of antennas technologies and radio modules will be needed to enhance throughput, improve coverage, reduce interference and save energy. As far as coverage the reality shows that the "star" architecture used for simulation does not meet the LOS constraint, thus daisy-chains with relays are more suitable. Actually, in the next section the physical parameters of the network elements, comprising the SARABAND network required to ensure the segment coverage and the expected capacity, will be specified.

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4.2. Network architecture

SARABAND architecture is a hierarchical, PMP IP-based network composed of nodes linked by radio transmissions, and remotely managed by a backhaul NMS instance. Figure 3 shows the proposed architecture for the network backhaul.

From the Fibre optics Point of Presence (PoP), the radio backhaul network uses ultra wide band radio configured for PMP. The covered areas are served by a spectrum bandwidth ranging from 250 MHz to 1 GHz (in the Q-band). These radio transmissions are composed of a multiplex of channels, aggregating several 100 Mbps half-duplex (TDD) channels to provide the required throughput, up to 2 Gbps half-duplex per 1 GHz radio transmission. Typical link capacity is up to 200 Mbps which can either be dedicated to MNO backhaul or shared in the case of access solutions for consumers and enterprises.

- Matching PtP Peak Capacity
- PMP within mmW Architecture
- All the benefits of PMP technology
- Maximising 3GHz of 42GHz

Small Cells with 100Mbits Peak

3G/4G Macro Site 200 Mbits

Fibre (PoP)

Transmission Hub offering up to 2Gbps

3G/4G Macro Site 200 Mbits

1-2km 99.99% availability   1-2km 99.99% availability
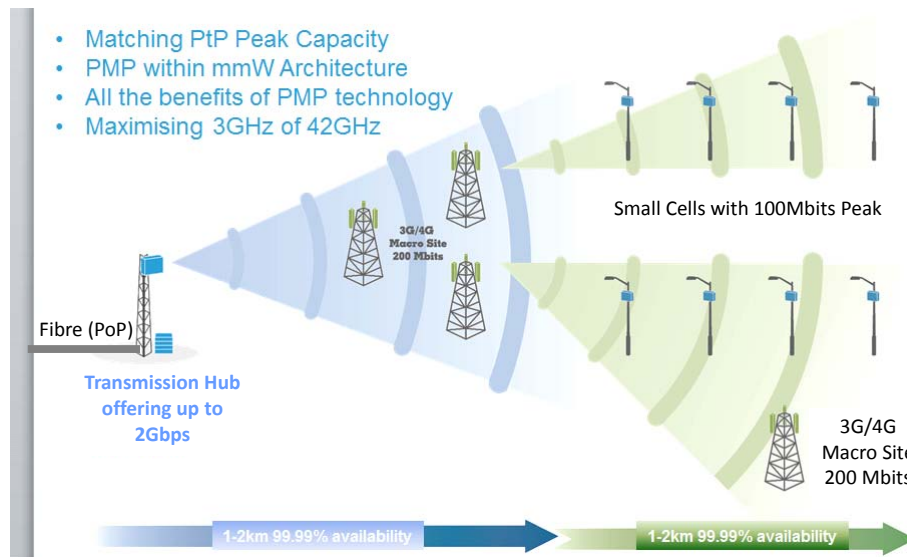
Figure 3. Backhaul architecture

Layer 1 and 2 of this network will be based on the 802.11n and then 802.11ac Standard and aggregation on 802.3ad. Routing is a serious and expensive thing, especially at multi-gigabit throughputs. So the architecture is based on VLAN which will use mainly switching techniques rather than routing ones to carry packets to their destination. This implies that the backhaul network is segmented in "Backhaul areas" able to deserve about 50 to 100 Points of Presence, in the way to limit broadcast issues. Concerning latency issues, the latency on the modems and radio is 2ms, being better than most Ethernet Gigabit transmission systems.

The network is composed of two main types of nodes:

- Transmission Hubs (TH) to carry traffic in the core network, and to connect several terminals or a relay node (RN). A RN comprises a TH which represents the Hub part PMP down stream and an upstream link, with an NTE connected to a PoP in the upper part of the network.
- Network Terminal Equipments (NTE) to deliver basic Service Interfaces to customer's Points of Presence. They establish a single connectivity to the TH where they are connected through a VLAN for each of them.

These networks nodes are composed of different elements such as radio frequency modules, multiplexers, modems and antennas. A detailed picture of the backhaul network is shown in Figure 4.
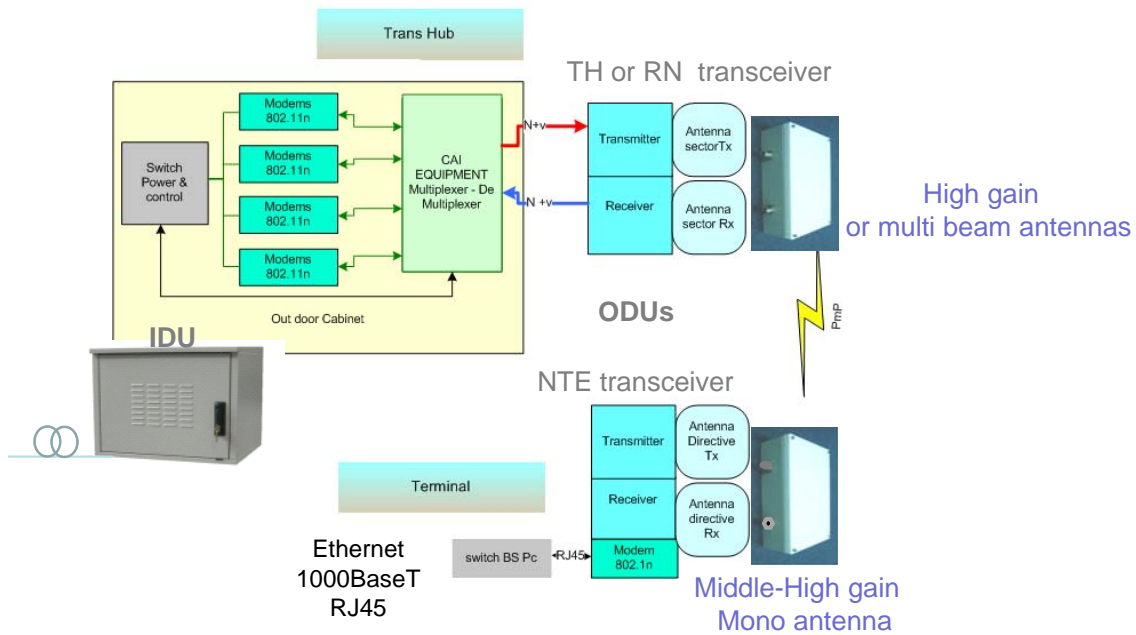
Figure 4. Backhaul elements

The TH comprises a transmitter (Tx), a receiver (Rx) with sector antennas (programmable multi-beam antennas). The Tx and the Rx are connected to a multiplexer and de-multiplexer named CAI (C-band Air Interface). The CAI is connected to a stack of modems (from 4 to 20). The wave form is based on the standard 802.11n. At the transmission hub the modems are configured as «MU» or Master Unit. These modems are plugged on an Ethernet switch which performs the aggregation (802.3ad). Relay Node is also a transmission Hub plus a link "upstream" (NTE to the TH).

On the other hand, the NTE comprises a transceiver with directive antennas. The transceiver is connected to a modem 802.11n configured as «SU» or Slave Unit through a combiner splitter. Therefore, the key point is now to define the performances of the network to specify the radios and antennas parameters in order to ensure the segment coverage and the expected capacity and throughput on each segment of the network.

4.3. Network element specifications

In order to specify the radio and antenna parameters required to guarantee the expected capacity and throughputs, we first built a complete model of the system TH-NTE including all gain and losses of the sub-assemblies, the propagation model, antenna diagram, channelization isolation, etc, in order to compute all the link budgets.

The model includes configuration product parameters (characteristics of TH, NTE, CAI, and modems), parameters related to network configuration under defined climatic conditions (distance from NTE to TH, position of the NTE related to TH antenna beams, temperature range, etc), and parameters related to the configuration of the modem. All these parameters are detailed in Table 2 and correspond to the performances of first generation Q-band products developed by BLUWAN. These products follows the EN 301 997 standard and are certified by Veritas.

This model derives the best frequency and power for each channel and associated modem and tunes the variable gain amplifiers of the Tx and Rx at the hub. As a result it provides the best throughput that can be obtained in a given configuration. All outputs are fed to the NMS (Network Management System) for configuration and supervision. Then, the NMS displays the C/N and relevant acceptable order of modulation which leads to throughputs as presented in Table 3.

Internal product parameters

	Tx		Rx		Multiplex CAI				Modems	
	TH	NTE	TH & NTE				TH	NTE		Value
P_{sat}	26	26	NF	5.5	Muxtiplex	isolation, dB	30	-	Frequencies (MHz)	4900-5900
P_{1dBm}	23	23	Rx_{sat}	-30	CAI-16, S_{12}	Loss, dB	11	-	Channel width (MHz)	10-20-40
16QAM	6	6			CAI-2, S_{11}	Loss, dB	-	2	Step frequency (MHz)	1
$G_{TX\ 0º}$	22	22	$G_{R\ max}$	34	G_{tx}	VGA, dB	0-30	-	Channel separation (MHz)	12.5-25-50
G_e Ant	16	28	$G_{R\ TH}$	16	G_{rx}	VGA, dB	0-30	-	Isolation between channels (dBc)	-45
			$G_{Rx\ NTE}$	28	BW	5100-5800 MHz	3, dB	-	RSSI, max (dBm): min (dBm):	-75 -25
L_e	0	0	L_e	0						-10/+18

Network configuration			Configuration of the modem				
Temperature & rain zone for 99.9%: Rain F db/km: 7.5			Modems: Channel width of 40 MHz Modulation order 16QAM: 6				
NTE	Dist. TH-NTE (m)	NTE axis offset (º) @ TH sector	VGA (dB)	NTE	IF MHz Freq. of modem	P_i dBm (NTE)	P_i dBm (TH)
1	800	40	VGA Rx:	1	5500	-5	1
2	600	40		2	5250	-6	-3
3	500	30	16	3	5550	-10	-7
4	700	20	Marge:	4	5300	-6	-3
5	550	10	2.9	5	5600	-10	-7
6	800	10	VGA	6	5350	-5	-2
7	350	20	Tx:	7	5650	-10	-10
8	800	20	12	8	5400	-5	-2

Table 2. Parameters of the configuration model

IF channelization			Uplink chain	Result
Channel width (MHz)	Proposed modulation	Applied modulation	Q band Pw emitted at NTE Tx (dBm)	Total aggregated throughput (Mbps)
40	QPSK	QPSK	21,0	40
40	16QAM	16QAM	13,9	80
40	QPSK	QPSK	21,0	40
40	16QAM	16QAM	13,1	80
40	16QAM	16QAM	18,0	80
40	16QAM	16QAM	18,0	54
40	16QAM	16QAM	12,2	80
40	16QAM	16QAM	9,2	80

Table 3. NMS display on C/N and throughputs

With Antennas, Tx and Rx parameters introduced, the simulation shows that PMP backhaul in millimetre waves has limitation either in throughput either in range and number of base stations connected. Indeed, we observed that with 8 NTE at 800 m the throughput is limited to 80 Mbps. To obtain more throughputs with more NTE at larger ranges a gain of 12 dB is at least needed. Evolution of power amplifier will provide 3 or at most 6 dB (but in that case we have problem of consumption and problems of filtering to comply with the regulation); noise figure could provide an improvement 2.5 dB as maximum. Thus classical way of evolution is not sufficient for our target. However, this 12-dB improvement can be obtained by improving the gain of antennas, which have to be very directive, and of high gain, being smart antennas the optimal solution. Then, we used again the model to specify the expected gain on antennas in order to meet operators' requirement and obtain the required performance of the network. The target parameters on the antenna and radio modules are specified in Table 4 and 5.

With these new antenna and radio parameters and increasing the number of NTE (16, in this case), the 150-Mbps-throughput on a NTE with a 1-km range required by small-cell LTE deployment is obtained.

RADIOS TH -RN	Parameters	Values	Variances +/-
Antennas	Gain dbi	36-22	+/-2db see spec antennas
Receiver Rx	Noise Factor db	4	0.5 over temperature range
	Saturation pin dbm	-30	
	Gain db	31	Temperature : +/-1.5db (T°1.5) Frequency : +/-1.5db (F 1.5)
Transmitter Tx	Psat dbm	29	T° 1.5; F 1.5
	P1 dbm	26	T° 1.5; F 1.5
	Gain db	26	T° 1.5; F 1.5
	Back-off db	-3,-6,-9	Depending on modulation order
RF Connections Multiplexer CAI	Loss Tx Rx db	0.5	+ 0 to + 0.5
Multiplex	Isolation db	30	-10 ; +3
CAI-16 S12	Loss db	11	0.5
Gain at Transmission	VGA db	0-30	1db precision
Gain at Reception	VGA db	0-30	1db precision
Bandwidth	5100 -5800 MHz	3db	+/-3db

Table 4. Target parameters of the radio modules and antennas of TH-RN

RADIOS NTE	Parameters	Values	Variances +/-
Antennas NTE	Gain dBi	30	+/-3db
Receiver Rx	Noise Factor dB	6	0.5 over temperature range
	Saturation pin dbm	-30	
	Gain dB	30	T°1.5 ; F 1.5
Transmitter	Psat dbm	19	T° 1.5; F1.5
	P1 dBm	16	T° 1.5; F1.5
	Gain dB	21	T° 1.5; F1.5
	Back-off	-3,-6,-9	Modulation order
RF Connections	Loss db	2	+0 to 0.5
Multiplexer CAI			
CAI-2 S11	Loss dB	2	0.2

Table 5. Target parameters of the radio modules and antennas of NTE

These results point out that TH-RN antennas should have a 36-dB$_i$ gain, RN-NTE a gain of 24 dB$_i$ and NTE antenna a gain of 30 dB$_i$ (Table 6). To obtain the target gains on each network segment, novel antenna technology in Q-band by exploiting sub-wavelength Lens and Circular Switched Parasitic Array (CSPA) technologies to design small form factor, programmable, high gain, and multi-beam antennas will be developed. Actually, on-going antenna development within SARABAND project show promising results. In a later stage of the project, a final demonstrator integrating all this equipment will be developed.

Application	Capacity	Range	Gain	Dimension
Lens Antenna				
TH-RN transport	Gigabits	1-3 km	35-36 dB$_i$	25 cm
RN-NTE Backhaul	n x 120 Mbps	300 m – 1 km	21-24 dB$_i$	< 20 cm
NTE terminal			30 dB$_i$	< 20 cm
CSPA Antenna				
RN steering antenna	p x 120 Mbps	500 m	16 dB$_i$	-

Table 6. Target antenna gains on each network segment

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5. Techno-economic study of SARABAND solution

To appreciate the real impact of the proposed PMP solution, a techno-economic study comparing PMP TCO versus microwave links TCO is addressed. This study considers the major CAPEX and OPEX drivers for an operator looking to deliver high capacity fixed data services using PMP and PTP systems in a hypothetical network with *n* endpoints being serviced from a central Point of Presence.

The major CAPEX considered in the economic analysis are:

- *Radio masthead and subscriber unit costs:* Traditional PTP microwave architecture requires large antenna dishes at each end of a link. In a PMP solution the central PMP base station serves simpler and less costly subscriber units which are placed at the endpoints. Hence: *(2n x PTP radio mast head) cost > (PMP base station + n x subscriber units) cost.* For simplicity masthead unit costs are identical for both solutions and subscriber unit cost for a PMP solution is 20% of a masthead unit cost.
- *Installation costs:* Installing radio mastheads is costly and a PTP solution requires *2n* radio masts as compared to a PMP solution, being the installation cost for PMP 25% of PTP.
- *Planning applications:* Traditional PTP solutions require dedicated radio mastheads at each end of a radio link. In certain geographies this can require a planning application for each radio masthead, which is not only a costly exercise but also time consuming. A PMP solution with simpler subscriber units simplifies and reduces the cost of the planning process (planning costs for PMP is 25% of PTP).

On the other hand, the major OPEX considered are:

- *Site rental:* Increasing site rental costs have become a significant OPEX element of an operators' business case. With simpler subscriber units, a PMP solution can significantly reduce site rental costs. (PMP costs are 25% of PTP).
- *Spectrum fees:* A PMP architecture can efficiently manage scarce spectrum resources as it can dynamically allocate capacity amongst *n* endpoints. With PTP, an operator is forced to dedicate spectrum to each link which can be inflexible and can typically be more expensive in terms of spectrum fees.

Taking into account all these points, Figure 5 shows a macro level view of the CAPEX and OPEX for PMP and PTP architectures over 5 years.
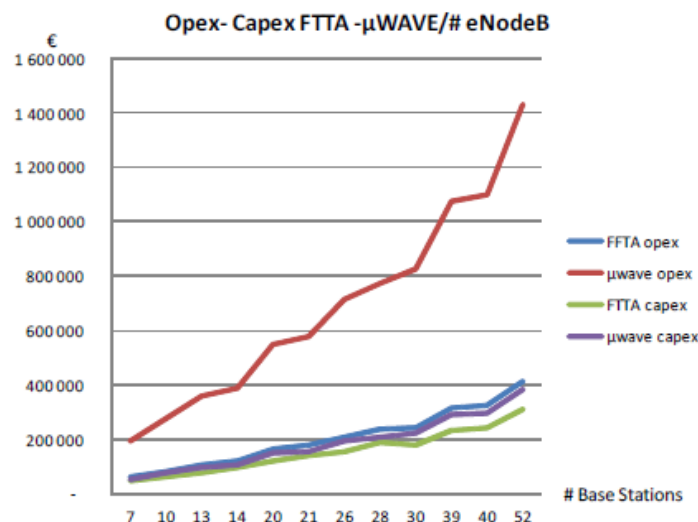

Figure 5. High level comparison of CAPEX and OPEX for PMP and PTP architectures

This figure clarifies the key cost drivers and how a PMP solution can be a more cost-effective solution for operators looking to deliver high capacity fixed wireless data services

at a low TCO. Actually, OPEX in cities is very high and µWAVE links CAPEX decreased dramatically. PMP solution typically requires less than half the hardware for coverage over PTP showing reduction in OPEX of up to 70% and, with larges series in the future, it will show reductions in CAPEX of up to 30% (not included yet on Figure 5) In addition, operators can maximize their return on investments by enabling faster time to revenue. Therefore, a PMP solution when combined with large blocks of contiguous TDD spectrum available at higher bands such as 42 GHz, can deliver a cost effective, flexible and high capacity wireless solution.

6. Conclusions

An analysis of the operational needs has been done with a dozen of operators. Capacity, throughputs and deployment parameters have been synthesised. A model of the point to multipoint system including propagations antennas, radios and modems multiplex has been developed. This model provides the parameters configuration of the system and delivers its performances as a function of the antennas and radio main values (power, noise factor, gains and losses...).

With this model and operational values, the study has defined the network hierarchical architecture upon a multiplex TDD and VLANs. Then specifications of the radios and antennas have been completed to meet the full performances. Finally, a techno-economic analysis has been performed.

References
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