SMALL CELLS BACKHAUL

STRATEGIC WHITE PAPER

Small cells backhaul presents a number of challenges to mobile operators because of the wide range of applications they support. In considering the backhaul options, answers to several questions must first be understood. Critical among these are:

- Will the small cells be used for providing coverage or for adding capacity?
- Will they need to seamlessly provide the same mobility services as macro cells, or will they be providing data offload?

These two questions alone will drive important decisions regarding ownership of the backhaul, the extent to which backup power must be employed, and how operation expense (OPEX), such as site visits, are controlled.

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FUNDAMENTALS

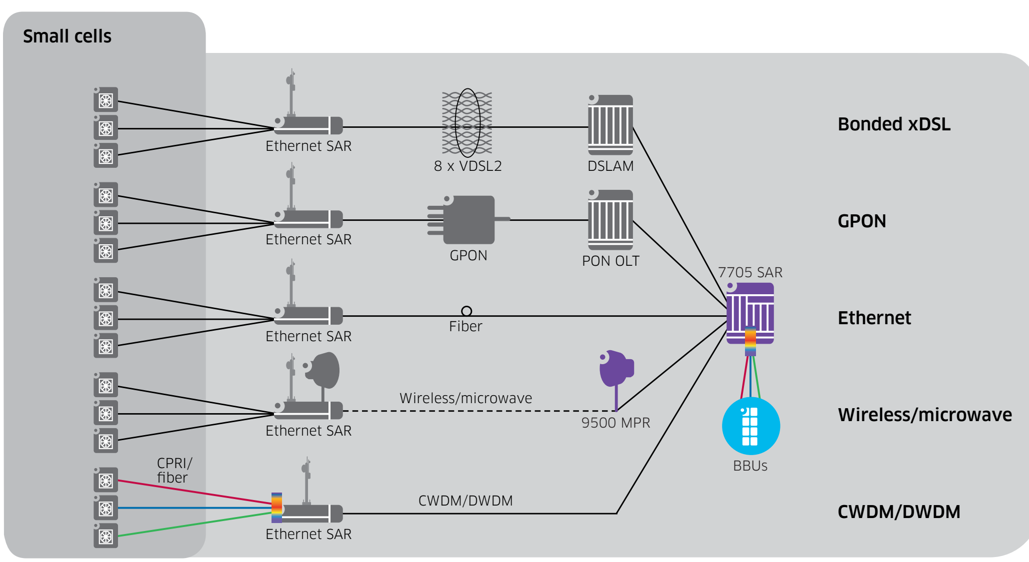
Principle to the backhaul of small cells is an understanding of the throughput per small cell required. Table 1 outlines the amount of throughput that can be anticipated in the upload and download directions based on the capacity of Long Term Evolution (LTE) at various bandwidths.

Table 1. Uplink and downlink throughput requirements based on LTE

LTE AT VARIOUS BANDWIDTHS					
		3 MHz	5 MHz	10 MHz	20 MHz
Downlink	Theoretical peak	16.8 Mb/s	28.8 Mb/s	60.2 Mb/s	145.6 Mb/s
	Aggregate average	3.6 Mb/s	6 Mb/s	12 Mb/s	24 Mb/s
Uplink	Theoretical peak	4.4 Mb/s	8.9 Mb/s	18.2 Mb/s	41.9 Mb/s
	Aggregate average	1.6 Mb/s	3 Mb/s	6 Mb/s	12.3 Mb/s

The throughput needs in Table 1 can be satisfied in a number of ways, as identified below in Figure 1.

Figure 1. Metro cell backhaul options



With specific reference to a digital subscriber line (xDSL) as a backhaul medium, the throughput will be governed largely by distance. Table 2 provides a view on what is possible using very high bit-rate digital subscriber line 2 (VDSL2).

Table 2. Typical rate/reach of VDSL2 to satisfy LTE at 10 MHz bandwidth

VDSL2 REACH IN FEET TO SERVE 10 MHZ LTE SPECTRUM CAPACITY TARGET RATE: 60.2 MB/S DOWN – 18.2 MB/S UP			
Pairs	60.2 Mb/s downlink	18.2 Mb/s uplink	Maximum
1	~1,400 ft.	N/A	N/A
2	2,500 ft.	2,100 ft.	2,100 ft.
4	4,500 ft.	3,000 ft.	3,000 ft.
8	>6,000 ft.	~3,400	3,400 ft.

Naturally, several constraints in addition to throughput must be considered. Chief among these is synchronization.

As synchronization pertains to LTE, there are different requirements depending on whether frequency division duplex (FDD) or time division duplex (TDD) is being used as the air interface, and what types of services are being provided over each. In addition, there are some constraints that pertain to handover of either data or voice calls to existing 3G technologies. Table 3 provides an overview of the constraints surrounding these.

Table 3. General synchronization requirements of small cells*

		SYNCHRONIZATION REQUIREMENT		SYNCHRONIZATION OPTIONS			
		Frequency	Phase	GPS	1588v2		SyncE
					Freq+only	Freq+phase	
Base technology	LTE FDD	50 ppb	N/A	OK	OK	OK	OK
	LTE TDD	50 ppb	1.5 µs	OK	Not OK	OK	Not OK
Timing requirements	Measurement-based HO to eHRPD/ e1xCSFB	N/A	10 µs	OK	Not OK	OK	Not OK
	OTDOA for E911	N/A	100 ns	OK	Not OK	Not OK	Not OK
	eMBMS	N/A	1.5 µs	OK	Not OK	OK	Not OK
	eICIC	N/A	1.5 µs	OK	Not OK	OK	Not OK
	CoMP	N/A	1.5 µs	OK	Not OK	OK	Not OK
	W-CDMA HO	50 ppb	N/A	OK	OK	OK	OK

* Only intended as a general guide, please refer to vendor for specific requirements

MAINTAINING QOS

The types of services to be provided using small cells dictate the quality of service (QoS) requirements for the backhaul network. Many mobile operators intend for small cells to act as an integral part of the radio access network (RAN), seamlessly providing all the same mobility services as the macro cells including voice, streaming video, multimedia, and best-effort data. In these cases, service level agreements (SLAs) for small cell backhaul must be consistent with macro cell backhaul SLAs independent of whether the network is self-built, leased, or a combination of both.

The key SLA metrics having a direct impact on mobile subscribers are packet delay (latency), packet delay variation (jitter), and packet loss. It is important that any small cell backhaul solution supports the following attributes independent of the access mechanism employed:

- End-to-end performance monitoring
- End-to-end QoS support
- End-to-end resiliency

To ensure the appropriate SLA performance is achieved for macro cell backhaul, many operators — mobile operators and backhaul transport providers alike — have operationalized, and often automated, a set of operations, administration, and maintenance (OAM) tools and procedures. Reusing these investments for small cell backhaul can offer significant OPEX savings compared to inventing new tools and procedures.

If a mobile operator plans to provide only best-effort voice and data services using small cells, then SLA requirements can be relaxed. This opens the door to lower cost backhaul options that are not generally acceptable for macro cell site backhaul. The degree to which the SLAs may be relaxed depends on the quality of experience (QoE) to be provided. In extreme cases, there may not be any SLA guarantees possible.

A good example of this is residential femto cells in which backhaul is typically provided using the subscriber's own Internet service provider. While both voice and data services may be offered, no expectations can be established or maintained regarding the subscriber's QoE as the connection passes through a generic Internet connection.

A similar paradigm might exist for enterprise cell service in which customers are using generic Internet access to connect. However, operators are cautioned to plan ahead. If a higher QoE is intended for small cells in the future, significant savings in total cost of ownership (TCO) can be achieved by deploying the appropriate backhaul solution at the initial site visit rather than deploying best-effort backhaul initially, then having to revisit every site to rip, replace, and migrate later.

In cases where small cells are filling coverage holes and providing "telecommunications services" the availability (uptime) of both the small cell and backhaul generally need to be comparable to that of a macro cell. This implies the need for highly reliable backhaul, end to end. Some mobile operators may even opt for battery backup to protect against AC power outages in order to maximize uptime of both the small cell and co-located backhaul equipment.

Where small cells are augmenting capacity of a macro cell, the small cell availability requirement may be relaxed somewhat recognizing that subscriber access can fall back to the macro network. Of course, the subscriber's QoE is also impacted in such cases. Thus some mobile operators may opt to reduce small cell deployment costs by avoiding battery backup but maintain the requirement for high availability backhaul (that is, accept the risk of power failure while mitigating other risks in the end-to-end backhaul path).

OTHER CONSIDERATIONS

It is essential that backhaul networks be designed for smooth scalability, maintainability, and fast, efficient installation of small cells. A scalable architecture ensures that the backhaul network can grow quickly and cost effectively to keep pace with the deployment of small cells, while designing in maintainability reduces the number of required site visits, keeping operational costs low. Designing the backhaul network for the simplified installation and turnup of small cells also guarantees faster deployments and time to market.

While the selection of certain site locations for the deployment of small cells might result in a higher cost of backhaul than otherwise anticipated, other benefits might offset these, including friendly landlords, lower site rental costs, availability of lower cost power, and easier accessibility for installation and maintenance.

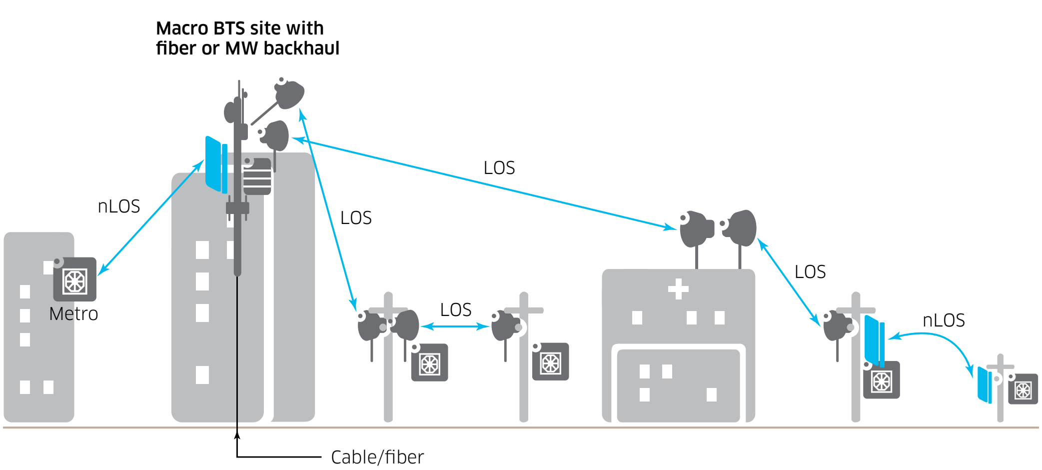
Backhaul "reachability" is an important factor in determining site locations. Fixed line access (for example, point-to-point fiber, gigabit passive optical network [GPON], and bonded xDSL) and line of sight (LOS) wireless connectivity provide the best QoS performance for backhaul. In occurrences where these access options are not available or where QoS requirements are relaxed, non-LOS (NLOS) wireless options can also be considered.

Table 4. Comparison of backhaul technologies

	THROUGHPUT	PROS	CONS	DOWNSTREAM LATENCY	UPSTREAM LATENCY
DSL	2-pair VDSL2 up to 100 Mb/s	Low capacity	Asymmetric bandwidth constraints; bandwidth is distance-limited	<50 us 60/80 GHz	<50 us 60/80 GHz
	8-pair VDSL2 up to 350 Mb/s DS	More pairs, more capacity; 8 pairs helps overcome bandwidth challenge	Asymmetric bandwidth constraints; bandwidth is distance-limited	<50 us 60/80 GHz	<50 us 60/80 GHz
Fiber/GPON	≥ 100 Mb/s	Very high capacity, medium distance	Expensive if fiber not already in place; asymmetric bandwidth and delay	GPON: 0.2/0.3 ms	GPON: 0.6/1.5 ms
Microwave 60/80 GHz 6-38 GHz	100 Mb/s – up to 1 Gb/s	High bandwidth, preditctable performance; Short dist. <1 km (60/80 GHz) Med. dist. 1 km – 9 km (6-38 GHz)	Expensive; line of sight required	<50 µs 60/80 GHz <0.2 ms 6/38 GHz	<50 µs 60/80 GHz <0.2 ms 6/38 GHz
Non-line of sight (NLOS)	50 Mb/s to 100 Mb/s	Non-line of sight; Fast deployment	Unpredictable capacity; Lower availability spectrum	<3 ms	<3 ms
GE/10 GE over CWDM	Nx10 Gb/s per wavelength	Very high bandwidth; CWDM SFPs are temperature hardened; Good distance 40-80 km	More expensive than GPON; DWDM not temperature hardened	<50 µs	<50 µs

Any optimal small cell deployment strategy will likely involve the use of multiple backhaul topologies. For example, some small cells might be backhauled to a nearby macro cell site necessitating that the bandwidth of the existing macro backhaul be increased. In some cases, the mobile operator may have multiple co-located small cells serving different hotspots from a common low-rise rooftop. This may require a daisy chain or hub-spoke topologies using a combination of wireless technologies (LOS and NLOS) along with local aggregation. Because no single backhaul topology will be optimal in all use cases, having flexibility is critical to successful deployments.

Figure 2. Employing a mix of wireless backhaul topologies



Another important factor in backhaul options in metro environments is the visual impact of the equipment. Small cell deployments are likely to be in densely populated areas and placed on existing city infrastructure, making the deployments highly visible to the public. This visibility forces wireless backhaul equipment to have small integrated antennas that do not appear to be radiating. Moreover, it will will ease the acceptance and site acquisition aspects of deploying small cells.

ACHIEVING SCALE

To achieve the designed long-term volume of connections in a small cell network while minimizing expense, backhaul network bandwidth should be scalable at all aggregation points.

Where a Gigabit Ethernet (GigE) fiber interface once sufficed to aggregate dense urban macro cell sites, seamless evolution to 10GigE may be required in order to support the addition of small cells over time. Similarly, evolution from N x 10GigE to 100GigE may be required at the mobile switching center (MSC) where all traffic is collected.

Microwave links should be able to cost effectively scale using channel bonding techniques, and microwave networks should support increased IP/Ethernet network awareness. This maximizes network capacity and provides an evolution to fiber should microwave capacities be exceeded.

The following items summarize the key network scaling requirements to address the introduction of small cells:

- Ability to cost effectively scale physical layer access and aggregation
- Support for the increasing number of small cells using carrier Ethernet IPv4/IPv6, and IP virtual private network (VPN) services
- IP and optical expertise to address high capacity 10G and 100G networking

Controlling OPEX as small cells are scaled requires that multiple small cell site visits be eliminated and small cells be turned up efficiently and expeditiously. Doing this requires a consistent operational model. One solution is to ensure operational consistency with the macro cell network, thus leveraging existing back office investments. Addressing the operational challenges of small cells includes:

- Consistent operations with the macro network, including multiple RAN vendor backhaul support
- Auto configuration tools that can get thousands of small cells up and running
- Surgical troubleshooting tools to avoid costly cell site visits
- Possible access to planning, installation, and deployment professional services

SUMMARY

Backhaul is a significant infrastructure expense and containing it requires the flexibility to support many different small cells deployment situations — extracting maximum performance while maintaining the ability to cost effectively scale to meet future small cell demands in the process. However, backhaul must be considered in the context of an end-to-end connection between a small cell and the core network. These end-to-end backhaul connections must adhere to SLAs based on the situation and application at hand. With the introduction of small cells, the permutations become many. And defining clear backhaul strategies and operational models are more important than ever to minimize backhaul costs.