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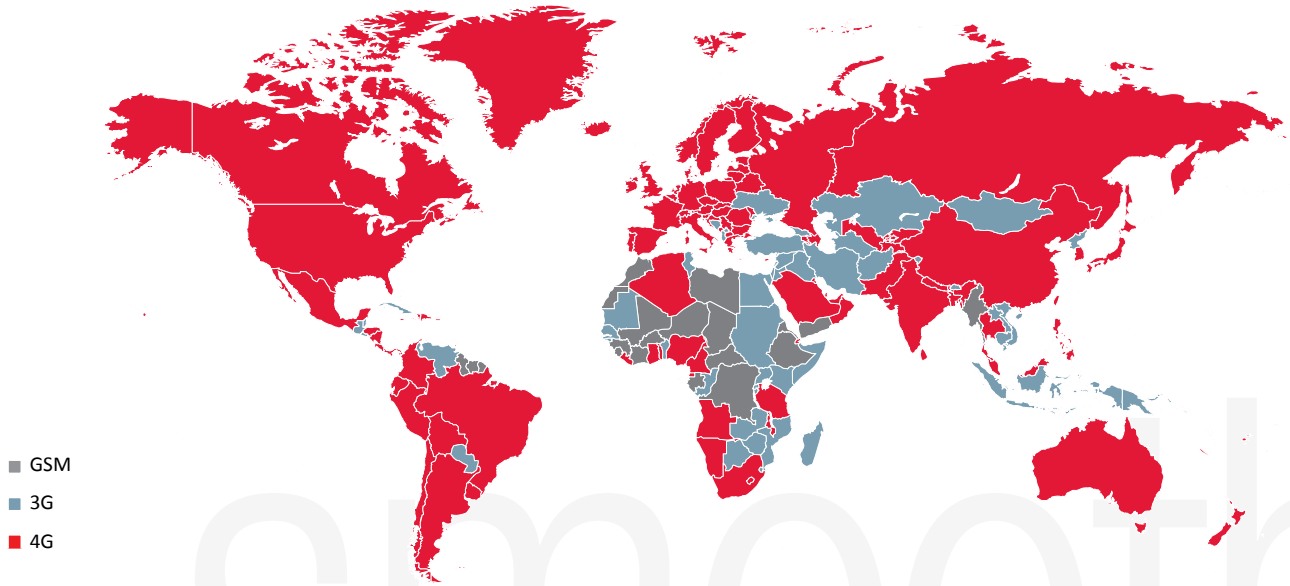
Transitioning the Backhaul Network to 4G and Beyond

Introduction

It is rare to find a mobile network operator (MNO) who is not dedicating considerable resources to projects for transitioning the backhaul network, along with the access network, to 4G. While there are occasional greenfield deployments, mainly undertaken by newly-licensed 4G network operators, most MNOs are modernizing their current 2G and 3G backhaul infrastructure to take advantage of 4G's considerable advantages. In fact, there are more than 100 current 4G implementations worldwide in various stages of deployment.



4G now covers most people on the planet

According to Deloitte, U.S. investment in 4G networks could fall in the range of $25-$53 billion, accounting for $73-$151 billion in GDP growth and 371,000-771,000 new jobs by 2016.

4G New network paradigm

4G backhaul networks constitute a very significant departure from traditional 2G and 3G technologies. 4G systems are based on packet architecture including the use of Ethernet physical interfaces for interconnection between the various network elements. The flat and simplified nature of 4G distributes more intelligence into the radios and eliminates radio controllers as separate devices. 4G disrupts 2G/3G's traditional hierarchical backhaul paradigm and promotes new deployment opportunities such as small cells and fronthaul concepts.

> "Although 4G connections represent only 2.9 percent of mobile connections today, they already account for 30 percent of mobile data traffic."
>
> Cisco Systems

wireless backhaul leadership

Since wireless solutions provide well-documented cost, deployment-speed and flexibility advantages, they maintain a leadership position in backhaul strategies for 4G.

Region	2012	2018
Africa	53%	55%
Asia-Pacific	33%	34%
Eastern Europe	24%	25%
Latin America	17%	19%
Middle East	51%	58%
North America	16%	20%
Western Europe	67%	60%

Adoption of 4G comes with a variety of backhaul opportunities and challenges. Primary among these are:

In this ebook, we will show how MNOs can gain significant competitive advantages as they transition their wireless backhaul networks to 4G and beyond. Careful planning today can guarantee customer satisfaction, cost savings and revenue opportunities well into the future.

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Chapter 1

Capacity and Coverage Expansion

Mobile connectivity is becoming a part of everyday life. Applications proliferate daily as do the numbers and types of devices that people use to connect. The trend is inevitable.

The future of networking holds many exciting possibilities. Mobile network operators must boost capacity and expand coverage to accommodate the mounting pressure for more, more, more!

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There are many market, technology and other trends that are causing a surge in the demand for capacity of the mobile network:

- Mobility is now a must-have. The sudden escalation in smartphone usage is just the tip of the iceberg. Tablets, wearables, and other quickly-adopted mobile devices are expanding the means for mobile connectivity. The trend toward Internet of Things (IoT) is predicted to add billions of additional connected devices to the already large and growing pool.
- Cloud computing and storage provide attractive economies of scale. Enterprises are storing more of their data and applications in the Cloud, opening them up to authenticated access from anywhere.
- Machine-to-machine (M2M) applications are enabling industries such as Energy and Mining to transfer monitor-and-control functions of machines and other assets from their remote settings, often expensive and difficult to reach, to easily accessible locations where concentrations of experts and technicians can be focused and costs are lower.
- Mobile applications, like video, are becoming abundant and, at the same time, more data-rich, requiring additional bandwidth and faster connectivity.

With 4G, mobile network operators have an exceptional opportunity to participate in supplying the bandwidth to cope with the surge in demand for mobile connectivity. But they must make sure that their backhaul networks evolve accordingly in order to deliver all of this mobile coverage and capacity affordably.

Connectivity everywhere

Backhaul is Always Capacity-Challenged

The traditional mobile network paradigm consists of macrocells (BTS) servicing high volumes of subscribers in a given territory with enough overlap between territories to maintain coverage and smooth handover as subscribers move about. Each macrocell is backhauled in hierarchical fashion to some higher-order aggregation point until it is ultimately connected to the network's core. As macrocells are added to cope with the surge in demand for mobile access and applications, they put additional capacity strains on the aggregators which, in turn, have to be upgraded, and so forth. Such is the life of the current backhaul network. Never a dull moment.

4G technology allows for the continuation of the traditional mobile network paradigm at higher speeds, greater capacities, and lower latencies than ever before. But it also introduces new economies of scale and opportunities. Under the 4G paradigm, backhaul capacity challenges can be met with a wider variety of solutions including implementing small cells, supersizing macrocells, and, a bit more futuristic, deploying fronthaul architectures.

up to

X6

capacity growth

Small Cells, Big Capacity

While a certain number of small cells have been deployed in 3G networks, they become a major part of the backhaul capacity-expansion strategy under 4G. Alone, a single small cell does not require very much capacity from the backhaul network. After all, a small cell's main purpose is to provide connectivity to a limited population of users in a concentrated area. However, as MNOs plan to deploy thousands upon thousands of small cells, collectively, their accumulated capacity pressure on the backhaul network is tremendous. So, network planners not only have to consider placement of small cells to increase coverage economically, but also have to take into consideration the capacity requirements for aggregating groups of small cells.

Today's advanced wireless solutions include moderate-capacity, short-distance solutions for aggregating small cells in small, medium and large clusters, up to ultra-high capacity, long-distance solutions to backhaul high volumes of traffic to distant aggregation points.

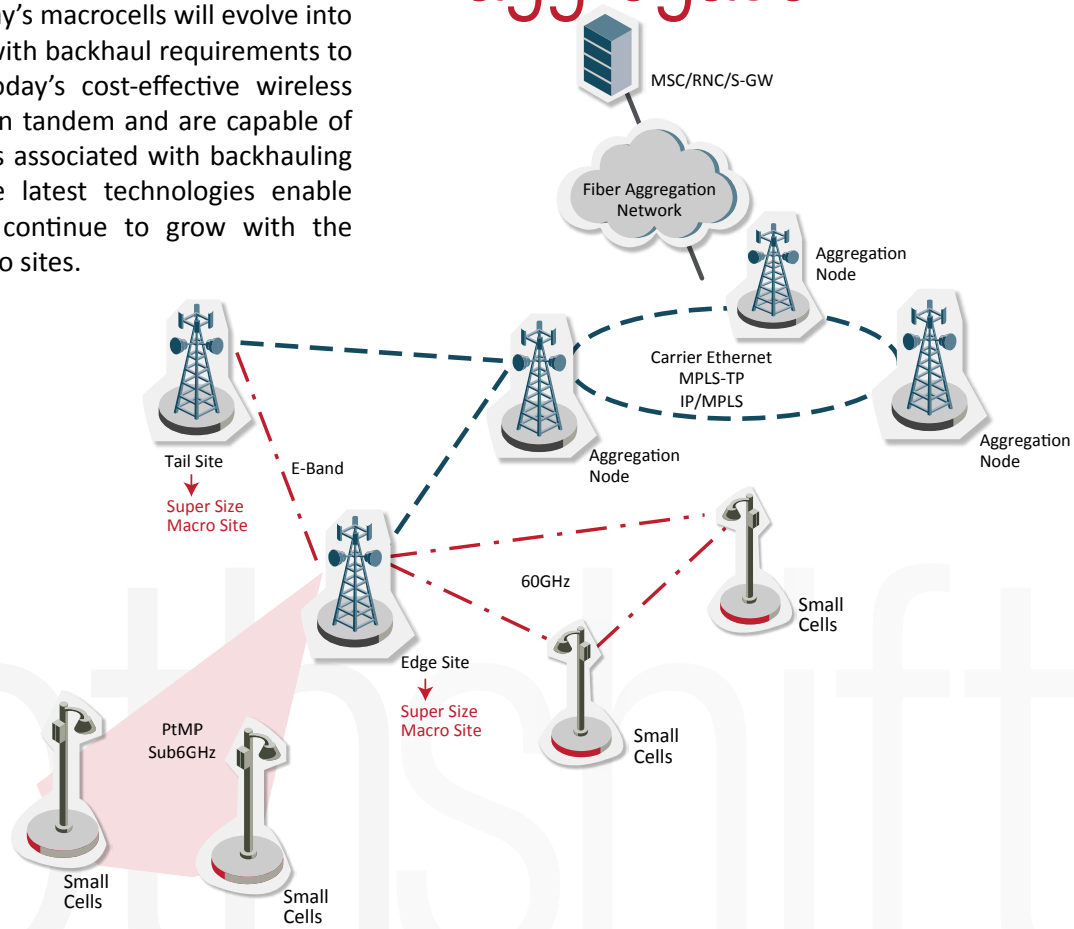
small cell aggregation

I'll have my macrocell super-sized, please

Macrocells are experiencing a surge in capacity requirements due to the increased capacity of 4G carrier aggregation and as they become hubs for small cells. This super-sized capacity cannot be handled by E1/DS1 multiples any longer, nor can it be satisfied by Fast Ethernet. If, in early LTE-ready backhaul deployments, it was considered future-proof to target 100-200 Mbps of capacity for tail sites, today's 4G requirements necessitate new capacity targets of 300Mbps to 1Gbps of backhaul throughput.

The evolution of urban tail sites, from 2G and its single Radio Access Technology (RAT) to Multi-RAT including 2G, 3G and 4G, all provided by the macrocell, will turn macrocells into small hub sites. Over time, as operators re-farm spectrum (reuse of 2G and/or 3G spectrum for 4G), for carrier aggregation and overall capacity in the small-cell network aggregated to this location, it is easy to see that the traditional tail site is evolving into a mini (and not-so-mini) aggregation site placing enormous capacity demands on the S1 interface toward the network core.

As 4G is deployed, today's macrocells will evolve into supersize macro sites with backhaul requirements to match. Fortunately, today's cost-effective wireless solutions have grown in tandem and are capable of meeting the challenges associated with backhauling Gbps of capacity. The latest technologies enable wireless solutions to continue to grow with the evolving needs of macro sites.



AT&T plans to expand its 4G network to cover more than 300 million Americans by the end of the year, and will densify its network in large cities by adding some 40,000 small cells.

Extending coverage

As demand for mobility expands, MNOs must extend territorial coverage to increasingly larger areas where people might want to use mobile networks. “Not spots” are disappearing!

Small cells for coverage

Whereas 2G access networks operate primarily in the 800, 900, 1800, and 1900MHz bands, and 3G access networks usually operate in the 2100MHz band, many 4G access networks will have to find their home in higher bands due to spectrum restrictions. The laws of physics dictate that the higher the frequency, the greater the attenuation of radio signals. Therefore, in order to maintain current coverage areas as 4G is deployed, MNOs will need to densify their tail-site deployments. They will need to add considerably to their already-deployed 2G/3G sites.

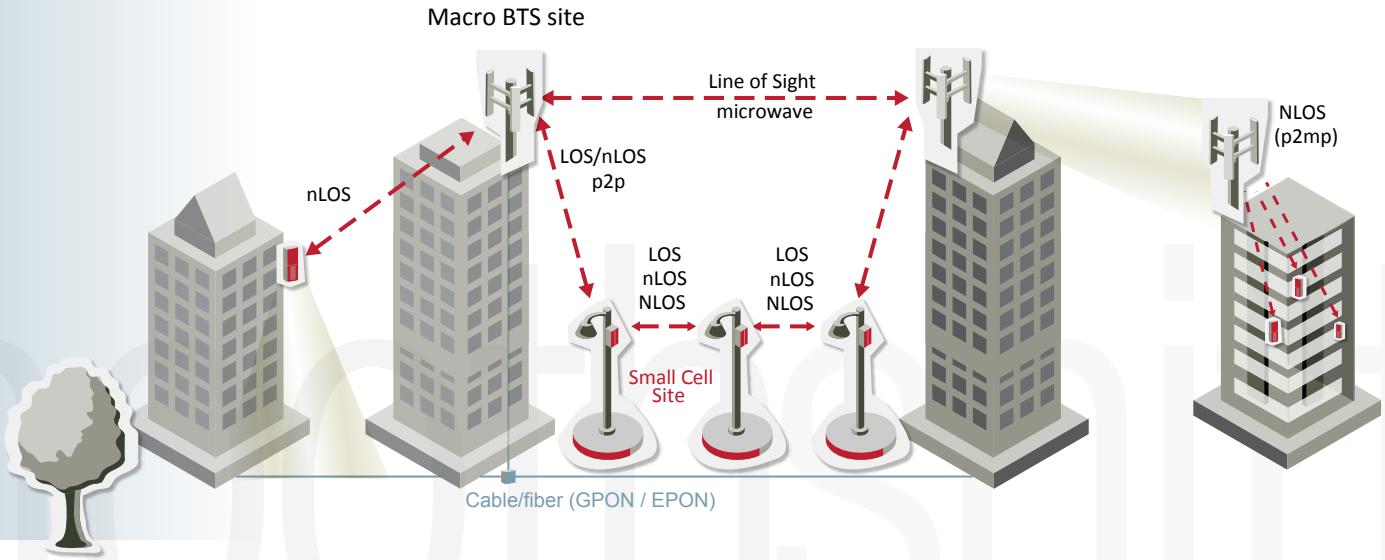
MNOs look to small cells to fill in the gaps among coverage areas as they transition to 4G. Compared to macrocells, small cells are far less expensive to deploy and operate since they consume far less power and are much more compact. As opposed to traditional rooftop and tower deployments, small cells can be located among street furniture in order to allow close-to-the-user deployment, filling small coverage gaps wherever needed. Placing small cells at the street level reduces signal propagation and thus reduces interference, perfect for the access network.

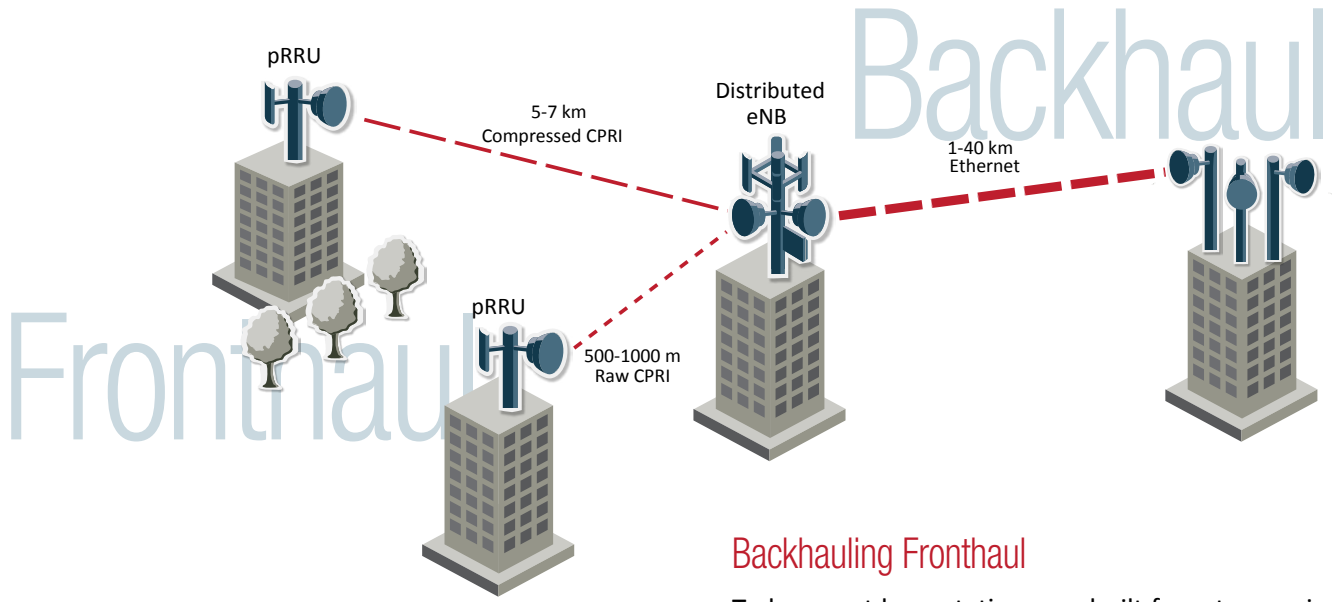
However, optimal placement of small cells for purposes of coverage are often less than ideal from the backhaul perspective. How do you connect street-level or in-building small cells to the rest of the network? In most cases, wire solutions, copper or fiber, are not available or too expensive to deploy. Outside of a few cases, most notably, Japan and South Korea, wired backhaul from small cells is not feasible.

Interference-free, uncongested milliwave spectrum, E-band and V-band, provide low-cost wireless backhaul solutions. Short in distance and high in capacity, milliwave spectrum offers an effective backhaul solution for a great many small cell deployments. For longer distances, high-capacity, compact, outdoor wireless solutions in licensed bands are ideal aggregators of groups of small cells. Point-to-point and point-to-multipoint solutions offer a wide range of backhaul network planning flexibility and cost-effective backhaul. For small cells in “tricky” locations, non-line-of-site wireless solutions can provide the necessary backhaul connectivity.

Variety of solutions

1. E-band and V-band for very high capacity over short distances.
2. High-capacity outdoor wireless solutions in licensed bands for medium and long-distance links.
3. Point-to-point and point-to-multipoint flexibility for a wide variety of cost-effective deployments.
4. Non-Line-of-Site solutions to move radio signals around buildings and other impediments.





Backhauling Fronthaul

Today, most base stations are built from two main units: a baseband or digital unit (DU) and a radio unit (RU). The interface between them is called the Common Public Radio Interface (CPRI). Originally developed for connecting the base of the tower to its top, CPRI is not very efficient in terms of bandwidth and has little latency or error tolerance. The CPRI interface from the DU to a single RU requires 2.5 Gbps of transport capacity to carry 20 MHz of LTE 2X2 MIMO with less than 0.1 ms delay.

Fronthaul deployment attempts to take advantage of the economies of scale of computing power. The idea behind fronthaul is to collect the DUs in a Cloud and to interface them with inexpensive and small RUs using CPRI, whether separated by a few meters or even as much as several kilometers. Fronthaul can save significant expenses in leasing space and air-conditioning. Imagine a case where dozens or even hundreds of RUs are connected to a pool of DUs residing in the Cloud. Additional gains are realized by use of shared-processing resources and dynamic allocation based on actual usage. Furthermore, since all the RUs are essentially connected to the same base station, interference mitigation can be performed very efficiently.

When compressed, a standard, low-latency, 1 Gbps wireless transport can carry the required load economically, promoting the business case for fronthaul. Wireless solutions are perfectly suited to carry this load between RUs and DUs whether over milliwave bands or licensed microwave bands. The various base stations, in turn, need to be backhauled and aggregated in the traditional fashion with the high-capacity wireless solutions.

Early fronthaul deployments can be found in China and South Korea. We expect the fronthaul concept to gain traction in the 2016-2020 timeframe.

Chapter 2

Revenue Opportunities

Despite the steep surge in mobile data consumption, mobile network operators find their profit margins under pressure. How can this be?

Competition and regulation are driving mobile network operators (MNOs) toward usage plans that bundle data and voice services at decreasing monthly rates, lowering subscriber ARPU.

But that's not the worst of it. The exploding number of value-added mobile services and applications are devouring backhaul bandwidth while not delivering any new revenues whatsoever.

How over-the-top is this?

Over-the-top content (OTT) refers to the delivery of HD streaming video, live television, audio and other media and services without mobile network operator involvement in the control or distribution. WhatsApp, Skype, YouTube, Netflix, Facebook and other third-party voice and video applications have become a multi-billion dollar problem for telecom companies, in general, and MNOs, in particular. In fact, according to telecoms analyst group, Ovum, the problem is going to get worse. as the telecommunications industry is set to lose a combined $386 billion between 2012 and 2018 from customers who use OTT applications.

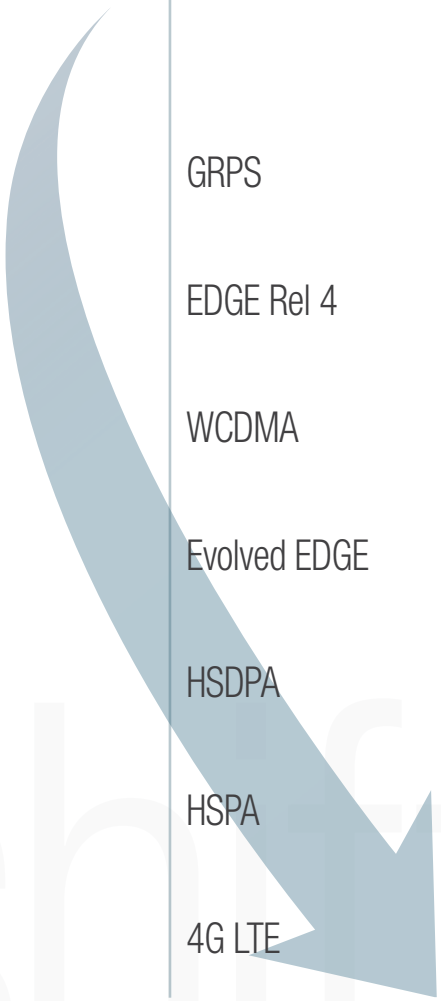
While OTT apps use up increasing volumes of backhaul network capacity, MNOs are effectively shut out from their revenue streams. Expected to deliver the mobility and backhaul capacity for these services, but without sufficient remuneration, MNOs are effectively being reduced to under-compensated transmission pipes.

Even profitable MNO services are under OTT siege. The era of high SMS margins, a major profit generator for many MNOs, is coming to an end as OTT applications like WhatsApp are devastating the traditional SMS money-machine.

Not only are SMS services affected. Subscribers invoke Skype, Viber and other VOIP applications to make free international voice and video calls, bypassing the MNO's profitable international tariffs and roaming charges and further cutting into the revenue stream. OTT players establish vast communities of loyal subscribers while MNOs watch on hungrily.

How can MNOs combat the relentless attacks of OTT apps on their revenue streams? Can 4G backhaul networks be instrumental in helping MNOs to boost their own revenues? Are there ways for MNOs to use 4G networks to offer more services that customers will pay for? Can 4G backhaul reduce costs as well, thereby making MNOs more profitable?

4G Lowering latency



Don't lag for network applications

A benefit of 4G that is related to customer quality of experience is **latency** or **lag time**. The lower the latency, the speedier the travel time through the network and the better the user experience. From the MNO perspective, reducing latency by half effectively doubles throughput speed without any other changes to the network.

The 4G LTE standard significantly reduces latency. Many applications that could not run successfully over mobile networks in the pre-4G days are now able to perform efficiently to the delight and convenience of mobile subscribers.

Here are two examples:

- Many new machine-to-machine (M2M) applications can operate over a mobile network.
- Electricity companies can surveil their substations in real time; mining operations can be monitored from remote locations; machines on deep-sea oil and gas platforms can be operated remotely saving money, time and personnel.
- HD multi-point video conferencing over mobile networks makes practical a new level of cost-effective and green communications capabilities. 4G latency improvements can bring the video conferencing experience to mobile networks.

Latency has repercussions for government, healthcare and other markets and industries as well. Coupling reduced latency and high bandwidth with differentiation of service capabilities, MNOs can take advantage of exciting new opportunities for providing the enhanced capabilities of real-time video surveillance, distance learning, expanded telemedicine and public safety. For example, remote medical personnel can discuss emergency steps with public-safety first responders while viewing events and receiving data from the field in real time.

SMARTNETWORK KILLERAPP

Deploy smartly with network intelligence

The new white knight enters the fray in 4G armor, providing opportunities for improving MNO revenue streams, slashing costs and enhancing subscriber satisfaction, all at the same time.

Today's most advanced wireless backhaul equipment takes advantage of computer power, the Cloud, programmability, and other techniques, features and methods to offer revenue-producing opportunities. While deployment costs can be substantial, the benefits are even more so. By committing to 4G backhaul and undertaking the transition with the latest wireless solutions, network operators acquire important weapons in the fight for better profit margins and can even gain an edge on the competition.

Intelligence optimizes the backhaul

Network intelligence is the MNO's killer app. Advanced levels of intelligence enable the backhaul network to sense, measure and react proactively to dynamic usage changes wherever they occur – locally, regionally, or even network-wide. The latest wireless backhaul networking solutions combine significant computing power with network intelligence to identify the immediate causes of congestion and bandwidth abuse exactly when and where they occur. Smart, Cloud-based monitor-and-control applications are able to re-allocate, reduce or expand backhaul capacity at necessary points based on numerous attributes like customer type, service level agreement and type of service. All of this indicates a faster, more flexible backhaul network that improves customer experience.

Taking cues from the data center and adding a few twists of their own, the latest wireless backhaul solutions can bring some new weapons to the fray. We will summarize three of these: Software Defined Networking (SDN), Network Functions Virtualization (NFV) and differentiation of services. The reader is encouraged to obtain deeper understanding of these subjects from white papers that can be found at www.ceragon.com and from blogs at www.backhaulforum.com.

SDN NFV

smart & flexible

By leveraging SDN and NFV, MNOs can contemplate solutions that, at once, lower costs and render mobile networks far more flexible and efficient. SDN and NFV separate the intelligence from the network element's hardware and move it into the data center or Cloud where big-data analytics can be leveraged to take optimal decisions network-wide. The network elements themselves are programmable and can be modified via software to accommodate immediate or long-term changes in network conditions and requirements. SDN and NFV enable wireless network solution vendors, 3rd parties and even the MNOs themselves to develop smart software applications that enable them to optimize and montetize the user experience.

SMARTNETWORK KILLER APP

Examples of what the new intelligence can do

Here are just a few examples of how the new intelligence can improve backhaul network efficiency dynamically and improve the customer experience.

Flow shaping

There is no value in sending traffic all the way to its destination if we know it will be dropped eventually along the way. For that, we need the capability to shape traffic at a flow-based level of granularity. With the proper intelligence, this can be accomplished quickly, and extraneous capacity can be allocated dynamically to other flows.

Flow re-routing

Adaptive Coding and Modulation in wireless links may trigger the re-routing of flows to different paths. Even though ITU G.8032, MSTP and IP-based Fast Re-route (FRR) can provide that capability, they cannot be aware of end-to-end network conditions. Cross-network intelligence provides visibility at the network level. The intelligent function that is required is one that knows how to handle many flows and can assign forwarding rules to each one.

Dynamic spectrum management

Network intelligence opens a new range of spectrum-optimization techniques at the network level. Ideas of joining interference measurement and dynamic spectrum allocation no longer seem like science fiction. They will allow order-of-magnitude more reuse of spectrum. Specifically, when block spectrum is used, a dynamic allocation application can monitor interferences on one side and utilization on the other, and can redistribute spectrum as needed either in symmetrical or asymmetrical arrangements.

Making dollars with sense

With all of this dynamic network intelligence, MNOs can differentiate between many types of customers and between many types of services. This differentiation promotes the development of new revenue streams. Here are some examples.

Selling excess backhaul capacity

Carriers of carriers (CoC) and alternative access vendors (AAV) build their businesses upon their deployment of backhaul capacity and then selling/leasing it to MNOs as an alternative to MNO self-deployment. Intelligent backhaul solutions enhance the ability of CoCs to sell guaranteed capacity to their MNO (and other) customers.

Mobile network operators and large enterprise network operators are able to get into this game as well. By evolving to high-capacity and intelligent 4G networks, they, too, can create and sell to others excess backhaul capacity. Public safety, utility and other network operators are candidates for hitching a ride on the MNOs' efficiently run, intelligent backhaul network.

Offering more bandwidth and SLA-based services

By being able to differentiate between numerous types of customers and services, MNOs can develop market plans based on the individual needs of specific enterprises and other customers. They can offer guaranteed bandwidth and service level-based services for a fee.

More to Come

Chapter 3 Keeping Customers Satisfied

For incumbent mobile network operators, the transition period to 4G will take place over a period of years. All the while, 2G and 3G subscribers are expected to remain with their respective access technologies according to the normal new-technology.

As they roll out their 4G networks, MNOs will continue to service these large 2G and 3G subscriber populations. What strategies are available for transitioning to 4G in a calculated and careful process that maintains customer service and loyalty as well as profitability?