NORTEL

White Paper

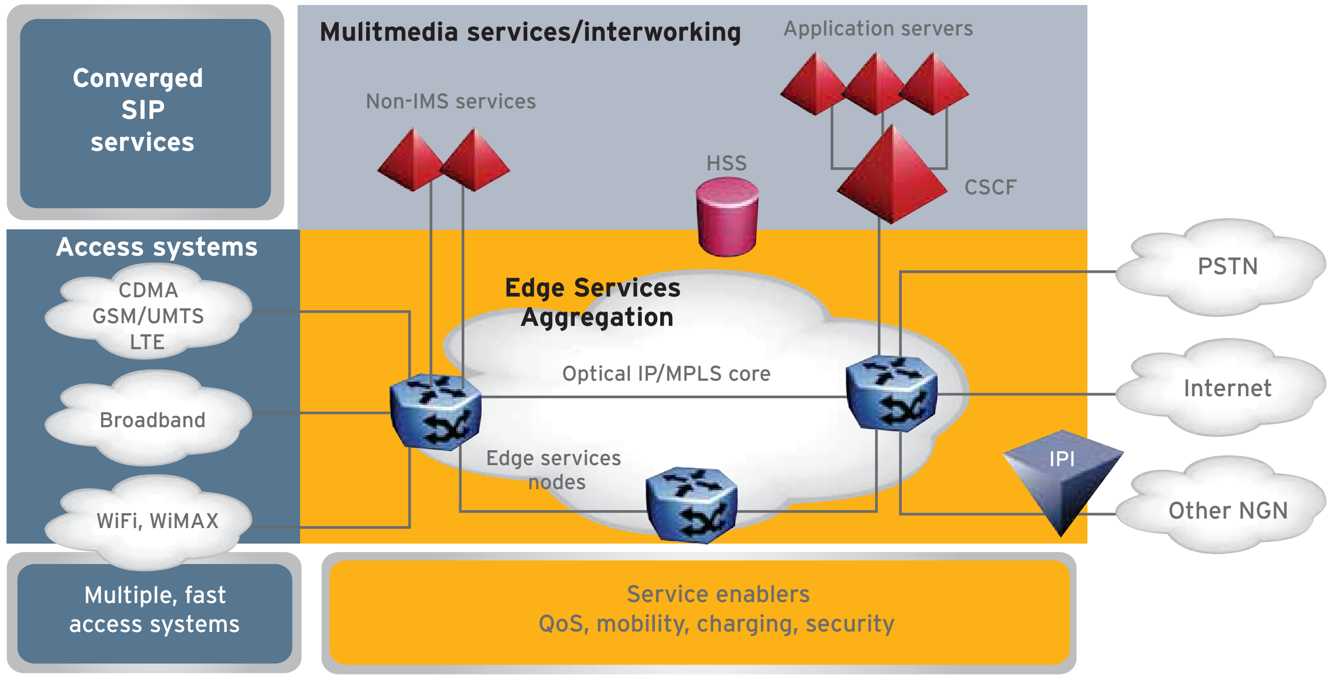
Long-Term Evolution (LTE): The vision beyond 3G

Mobile networks have enabled dramatic advances and changes in telecommunications over the last two decades, and mobile operators have grown to dominate the industry, offering their subscribers a service set as rich as their wireline competitors (i.e. mostly voice), plus mobility. However, with the broadband market success in cable, xDSL and Wi-Fi, the competitive landscape is changing.

Although 3G technologies deliver significantly higher bit rates than 2G technologies and contribute to ARPU growth for wireless data services, there is still more opportunity for wireless operators to capitalize on the ever-increasing demand for "wireless broadband", even lower latency and multi-megabit throughput. Consequently, there is an expanding revenue opportunity from a growing pool of underserved consumers that can only be satisfied with next-generation networks. The solution is "LTE" (3GPP Long Term Evolution), the next-generation network beyond 3G. In addition to enabling fixed to mobile migrations of Internet applications such as Voice over IP (VoIP), video streaming, music downloading, mobile TV and many others, LTE networks will also provide the capacity to support an explosion in demand for connectivity from a new generation of consumer devices tailored to those new mobile applications. Competing technologies are already emerging to address the growing nomadic wireless broadband market space and challenging the status quo. However, mobile operators, thanks to their incumbent position, have a unique opportunity to evolve their infrastructures to next-generation wireless networks and capitalize on this great opportunity to further grow their dominant market share. Their decision on which technology and when to evolve to the higher performing next-generation networks will underpin their market success.

LTE encompasses the pillars of next-generation networks:

- Broadband wireless as the new access reality — High-throughput, low-latency mobile access based on OFDM/MIMO, efficiently delivering unicast, multicast and broadcast media.
- Convergence of technology and networks — A single applications domain serving customers across multiple networks and devices.
- Intelligence at the services edge — Implementing policy enforcement and decisions at the network edge, in an access-agnostic but access-aware framework.



- Technology shift to all-IP — Simplifying and streamlining the network, improving scalability and deployment flexibility, and enabling consistent access-aware policy enforcement and billing.
- Embedded security — A multi-layer, multi-vendor approach to security is critical to ensure that security is endemic to the network and not just focused on point solutions.

These key concepts also lead to a target architecture characterized by a flat all-IP based multi-access core network, referred to as System Architecture Evolution (SAE).

Evolved wireless access: LTE

The challenge for next-generation wireless networks is to provide wireless broadband at a cost and performance better than that achievable with DSL technologies, while maintaining seamless mobility, service control and maximizing network capacity with limited spectrum resources.

Specific technical requirements include:

- Low latency and high throughput
- Efficient always-on operation, with instantaneous access to network resources
- Support for real-time and non-real-time applications
- Flexible spectrum allocations
- Re-use of existing cell site infrastructure
- High spectrum efficiency for unicast, multicast and broadcast data

In addition to the requirements above, there is a set of minimum performance requirements defined by the 3GPP Long-Term Evolution (LTE) studies. These objectives include:

- Increased spectral efficiency and capacity — LTE is expected to deliver three to five times greater capacity than the most advanced current 3G networks.
- Lower cost per bit — Increased spectral efficiency combined with the operational benefits of an all-IP network will reduce the cost per bit compared to 3G solutions.
- Improved quality of experience (QoE) — One of the benefits LTE/SAE will bring is a reduction in latency time, which will enhance the behavior of time-sensitive applications, such as VoIP, thus improving the user experience. For example, the latency time, expressed as the time for a 32-byte Ping, is expected to reach 20 ms (compared with 120 ms for a typical 3G network).

Two key enabling technologies will help the industry meet and exceed the LTE performance objectives:

- Orthogonal Frequency Division Multiplexing (OFDM) is intrinsically able to handle the most common radio frequency (RF) distortions without the need for complex equalization techniques, and scales easily to fit different bandwidth requirements.
- Multiple Input/Multiple Output (MIMO) increases peak throughput by transmitting and receiving multiple streams of information within the same spectrum. MIMO exploits the multi-path effects typical in wireless environments.

The combined use of OFDM and MIMO will improve the spectral efficiency and capacity of the wireless network, and will prove to be a very valuable asset in maximizing usage of scarce spectrum typically controlled by regulatory bodies.

OFDM is already an extremely successful access technology currently deployed in a number of wireless and wireline applications. These applications include broadcast (Digital Audio Broadcast or DAB, and Digital Video Broadcast or DVB), wireless WLAN (IEEE 802.11a and IEEE 802.11g), WiMAX (IEEE 802.16) and wireline Asynchronous Digital Subscriber Loop (ADSL/ADSL2+). OFDM is widely accepted as the basis for the air-interface necessary to meet the requirements for next-generation mobile networks.

MIMO employs multiple transmit and receive antennas to substantially enhance the air interface. It uses space-time coding of the same data stream mapped onto multiple transmit antennas, which is an improvement over traditional reception diversity schemes where only a single transmit antenna is deployed to extend the coverage of the cell. MIMO processing also exploits spatial multiplexing, allowing different data streams to be transmitted simultaneously from the different transmit antennas, to increase the end-user data rate and cell capacity. In addition, when knowledge of the radio channel is available at the transmitter (e.g. via feedback information from the receiver), MIMO can also implement beam-forming to further increase available data rates and spectrum efficiency.

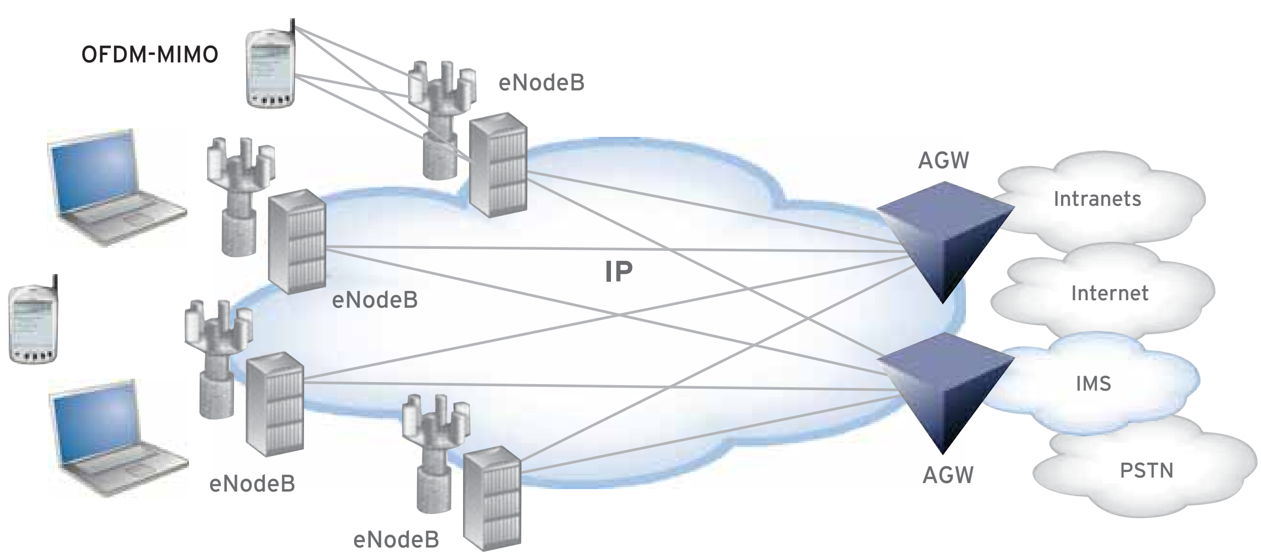
Nortel has shown that OFDM-MIMO with beam-forming — or Spatial Division Multiple Access (SDMA) — can provide a higher order of magnitude capacity on the downlink than current 3G deployments. Nortel has also shown how multiple antennas could be deployed on the user equipment, an especially challenging requirement with severe space constraints.

Nortel has been investing in OFDM and MIMO since 1998 in anticipation of their adoption in mobility networks. Since then, the company has demonstrated OFDM-MIMO commercial benefits and feasibility to more than 100 customers worldwide. Nortel continues to leverage its OFDM-MIMO investment and experience across 3GPP LTE, 3GPP2 UMB (Ultra Mobile Broadband - EVDO Rev C) and WiMAX to achieve maximum synergies across these advanced wireless network product lines.

Other key enabling technologies which Nortel is actively researching include metamaterial antennas, cell-site cable reduction and high-efficiency linear power amplifier technologies, which will all contribute to lowering the total cost of ownership benefiting from the OFDM-MIMO based LTE deployments.

Simplified architecture: SAE

To meet the technical and performance requirements noted previously requires a reduction in the number of network nodes involved in data processing and transport. A flatter network architecture leads to improved data latency (the transmission delay between the transmitter sending data and the receiver receiving it) and better support of delay-sensitive, interactive and real-time communications.



A typical LTE/SAE network will have two types of network elements supporting the user and control planes.

- The first is the new enhanced base station, so called "Evolved NodeB (eNodeB)" per 3GPP standards. This enhanced BTS provides the LTE air interface and performs radio resource management for the evolved access system.
- The second is the new Access GateWay (AGW). The AGW provides termination of the LTE bearer. It also acts as a mobility anchor point for the user plane. It implements key logical functions including MME (Mobility Management Entity) for the Control Plane and SAE PDN GW (System Architecture Evolution Packet Data Network GateWay) for the User Plane. These functions may be split into separate physical nodes, depending on the vendor-specific implementation.

Comparing the functional breakdown with existing 3G architecture:

- Radio Network elements functions, such as Radio Network Controller (RNC), are distributed between the AGW and the enhanced BTS (eNodeB).
- Core Network elements functions, such as SGSN and GGSN or PDSN (Packet Data Serving Node) and routers are distributed mostly towards the AGW.

Standards are expected to be 100% finalized by end of 2008.

Convergence and services edge

Key requirements focus on user quality of experience, service innovation and network simplification and evolution. Specifically, these include:

- Service-oriented architecture supporting diverse service classes
- Content-based charging
- Operator policy control of services and networks
- End-to-end QoS
- Service and network roaming support
- Technology co-existence
- Open interfaces
- Scalable, evolvable network elements

Adoption of a Service-oriented Architecture (SoA) is desirable in order to reduce the time spent from service creation (or development), to deployment, to execution, and therefore improve service innovation. SoA facilitates cost-effectiveness and acceleration of the time to move from conception to execution.

Content-based charging, operator policy control, QoS and roaming support are important concepts in order to sustain the value of key strategic assets (e.g. spectrum licenses, cell site infrastructure, brand) over the long term, and under roaming scenarios. They also contribute to improving end-user quality of experience.

All-IP flat networks

Using IP networking as the foundation for service delivery provides maximum flexibility, decouples the user and control planes to simplify the network and improve scalability, and allows the wealth of existing IETF standards to be leveraged. Specific requirements include:

- Optimal routing of traffic
- IP-based transport
- Seamless mobility (intra- and inter-Radio Access Technologies)
- Simplification of the network

Security

The security challenge with IP networks is one of the most significant factors that slows down the further adoption of network technologies. Operators and enterprises recognize the clear productivity improvements and cost savings of converging their communication technologies on a single infrastructure and enabling universal connectivity for users. However, they are hesitant to adopt technologies that may compromise their privacy, put their business at risk and potentially cause significant financial loss.

An end-to-end system approach to security is required in next-generation wireless networks, including:

- Platform hardening
- User/operator authentication, authorization and auditing
- Secure protocols, communication and data storage
- Software and configuration integrity
- Secure network management, control and signalling
- End-point compliance
- Network perimeter protection and interior protection
- Unsolicited traffic protection

Nortel is leading in OFDM-MIMO

Nortel is engaged in numerous activities directed towards realization of next-generation wireless networks. Specifically:

- Driving relevant initiatives across standards bodies: 3GPP, 3GPP2, 802.16e
- Partnerships for ecosystem development
- Terminal certification
- Open interfaces

Nortel views OFDM and MIMO as the fundamental building blocks for all future advanced wireless technologies. At 3G World Congress in 2005, Nortel publicly promoted the advantages of OFDM-MIMO to 3GPP operators, which accelerated its introduction into the 3GPP LTE standards.

In 2006, Nortel delivered an OFDM-MIMO prototype solution based on the Collaborative MIMO technology and achieved a connection speed in the uplink that was 15 times faster than today's fastest mobile connectivity. Nortel's original OFDM-MIMO laboratory prototype, demonstrated in 2004, delivered 37 Mbps in the downlink in the same bandwidth.

At 3GSM World Congress and CTIA in 2007, Nortel publicly demonstrated a pre-standards LTE air interface supporting video streaming and file transfers to multiple devices.

More recently, at Mobile World Congress and CTIA 2008, Nortel was again demonstrating a LIVE air LTE system, with embedded advanced radio functionalities to cope with the varying radio conditions, and showing examples of the hyperconnected lifestyle with multiple devices running advanced multimedia applications like High Definition video streaming, Microsoft Unified Communications, Social Networking applications and Video Collaboration to name a few. Nortel also announced in April 2008 that LTE calls at high vehicular speeds had been made, achieving download speeds over 50 Mbps at 110 Kmph, during customer visits to its centre of excellence in Ottawa.

Nortel will be conducting LTE trials with customers during 2008 and 2009, and is on track for delivery of commercial systems by end of 2009, in line with the availability of initial commercial devices.

Nortel's strategy includes early co-development partnerships with mobile chipset vendors and accelerated interoperability testing with device manufacturers. This will ensure the availability of a complete LTE ecosystem in alignment with Nortel's network solution. In addition, Nortel places an emphasis on technology leadership and simplicity in its LTE solution to achieve the lowest total cost of ownership for operators.

Nortel has also made significant investments in autonomous network management systems based on Self Organizing Networks, Touchless Installation and Autonomous RF Optimization to vastly simplify the way LTE networks will be deployed and managed.

Nortel is a technology leader with a clear vision, a proven innovation track record, and a commitment to best-in-class solutions. Nortel is in a unique position to provide a balanced vision on the technological landscape and its evolution, leveraging its experience and leadership in major wireless technologies, as well as in the optical, IP, MPLS and VoIP markets.

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