White Paper

Microwave Radio Backhaul in Wireless Public Critical Communications

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NOTICE

ABSTRACT

Wireless public safety networks[1] are in a flux, driven by emerging user requirements and expectations, such as live bidirectional video streaming and the real-time uploading and downloading of high-resolution pictures. These high data rate services call for an air interface throughput that lies one or even two orders of magnitude beyond the modest 10-150 kbps service capability of the legacy Time Division Multiplex-based radio access and data backhaul architectures supporting the majority of today's wireless public safety networks.

At the same time, while evolving towards multi-megabit-per-second throughputs, traditional values of public safety networks must be upheld. If remote and sparsely populated areas are to be illuminated with dependable service, service latency has to remain low and service availability needs to be exceptionally high. In addition, the network has to be both resilient against physical and cyberattacks or natural disasters and meet the highest standards in terms of network integrity and data confidentiality.

This article explains why the third generation of rugged, all-outdoor, high-capacity packet microwave radios is an ideal backhaul engine for wireless public safety networks. As a secondary goal, it will examine why LTE[2] stands a good chance of powering the air interface of broadband-enabled wireless public safety networks.

LTE FOR BROADBAND RADIO ACCESSS WIRELESS PUBLIC SAFETY NETWORKS

The critical communications market is an attractive market segment for telecommunications equipment vendors and services providers. The total market size is expected to exceed two billion US Dollars in 2019[3]. Against this backdrop, leading equipment vendors and the 3rd Generation Partnership Project (3GPP) position LTE as *the* technology of choice for implementing the radio access portion of wireless public safety networks. The radio access part of a wireless network – including the mobile backhaul – typically accounts for at least 70% of the total cost of ownership for the *entire* network. Understandably, the selection of a radio access solution features prominently in any investment decision.

From an investment perspective, the main argument favoring LTE as a radio access technology is its comparatively low cost compared to any other broadband radio access alternative, owing to its wide-spread use in public and commercial land-mobile networks around the globe[4]. LTE is ubiquitous and benefits from economies of scale and a large, mainstream global technology ecosystem. Investment and TCO[5] can be reduced to the barest minimum in case existing, commercial LTE networks are used as radio access providers for a public safety network[6], rather than a full-scale roll-out of a dedicated public-safety radio access network.

From a technological perspective, LTE can be a superb fit, too. After all, it was conceived and designed to support significantly lower latencies and materially higher bandwidths at a higher spectral efficiency than any other wireless technology serving mobile outdoor users.

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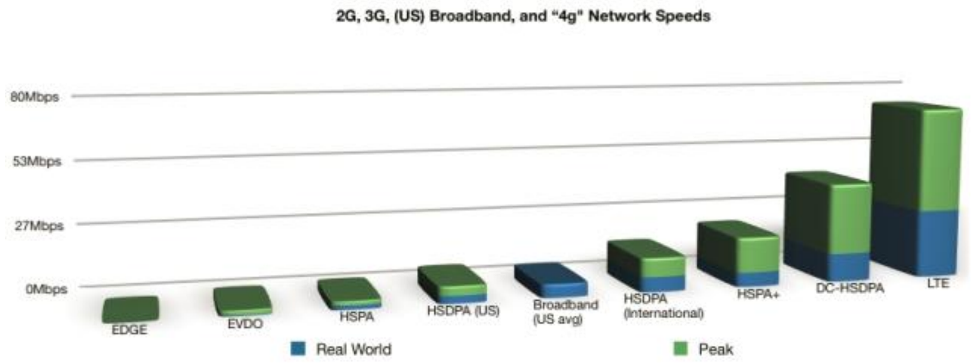
[1] Also referred to as Emergency Service Networks or ESNs.
[2] Long Term Evolution as standardized by 3GPP, the 3rd Generation Partnership Project.
[3] Source: Nokia.
[4] 339 commercial deployments in April 2015 according to the Global mobile Suppliers Association (GSA).
[5] Total Cost of Ownership.
[6] This approach is currently under consideration in the United Kingdom.



Typical and peak throughputs offered by different (wireless) broadband technologies. LTE reigns supreme.

There are a number of challenges to be overcome though, before we see LTE adopted as a radio access layer in next-generation broadband wireless public safety networks.

LTE was initially released with a rather limited scope, as a pure high-performance high spectral efficiency mobile broadband data solution *complementing* the widely-fielded 2G[7] and 3G[8] technologies. Initially, LTE was lacking even the most rudimentary and fundamental voice service capability: VoLTE[9]. It was certainly *not* conceived to be part of any public safety solution, wanting for essential public-safety network features, like for example direct mode, where user handsets can communicate directly if there is (temporarily) no network available and with no support for multiparty “push-to-talk” calls.

Those gaps in the LTE technical specification are now being addressed by 3GPP, as LTE standards are evolving towards embracing wireless public safety network requirements. The next 3GPP Release, Rel-13, which is due in 2016, could be the first LTE release truly capable of supporting wireless public safety applications comprehensively.

Once the LTE specifications are mature enough to support public safety applications, the LTE network equipment community will have to translate those specifications into tangible solutions. Specific public safety requirements have to be addressed, not just on the network infrastructure equipment and application side, but also on the portable handset side. Rugged, yet user-friendly and affordable waterproof, heat-resistant and shock-proof handsets, featuring extended battery-life and high transmit power[10] hold the key to success. Multi-mode devices, supporting both TETRA[11] / P25[12] and LTE standards may be required to smoothen the transition between current and next-generation wireless public safety networks.

No matter what technology or building blocks are selected, *good network design* and an excellent support organization is what will ultimately make or break a wireless public safety network. A careful balance needs to be stricken between system performance from an emergency service user perspective and the TCO constraints. Inevitably, single-minded TCO optimization will unlikely yield an acceptable user experience, as public safety networks ought to be built and maintained to more exacting standards than commercial networks.

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[7] Second Generation, digital voice centric wireless access technologies like GSM (GPRS/EDGE/EGPRS), CDMA and TETRA.

[8] Third Generation, more broadband data-centric wireless access technologies like WCDMA and WiMAX.

[9] Voice over LTE.

[10] Coverage is mostly up-link limited.

[11] Terrestrial Trunked Radio, a professional mobile radio and two-way transceiver specification, specifically designed for use by government agencies and emergency services.

[12] Project 25, the North-American TETRA equivalent.

Without striving for completeness, we'd like to highlight attributes that are exceptionally important for public safety (wireless) networks, but are normally not found – or not found to a sufficient degree – in commercial wireless networks. In addition, we suggest measures that can be taken in order to live up to emergency service providers' expectations:

1. *Superb geographical and in-building coverage:*
    - Use of lower frequency bands e.g. 450, 700 and 800 MHz,
    - Sufficient cell site count in low population-density areas,
    - Densification of cell sites in urban areas for better in-building penetration,
    - High power transmitters, especially in the emergency-service handsets, as coverage is mostly uplink-limited,
    - Dedicated indoor coverage for underground or large publicly-accessible structures like subways, airports, stadiums or shopping malls through DAS[13] or (indoor) small cells.

2. *End-user service availability approaching 100%:*
    - High cell site density – as high as affordable – leading to generous coverage overlap between adjacent sites; a single cell or even a single site failure should not compromise outdoor coverage,
    - Redundant and self-healing transport network *topology*, aiming to provide *at least* 2 topologically independent routes for connecting each base station in the network,
    - No single points of equipment failure in network segments or network elements that serve a large geographical area, complementing the cell site coverage and topological transport network redundancy,
    - Battery backup systems / electricity generators addressing extensive power outages,
    - Physically secured radio access sites under (camera) surveillance,
    - Isolated-mode support, where parts of the network get severed from the main body of the network, but still retain full service for users within its coverage realm,
    - Direct mode support between end-user devices and relay-mode[14] support,
    - 24/7 service organization distributed throughout the territory together with a supply of essential spare parts, able to guarantee a short MTTR[15],
    - 24/7 disaster–recovery teams, distributed throughout the territory, for prompt disaster recovery or rapid in-fill capacity or coverage provisioning, with at their disposal:
        i. Cells on wheels (or even ship-based/airborne cells), with microwave and fibre-based backhaul options,
        ii. Mobile microwave relay towers on wheels for quick establishment of backhaul capability where needed.
    - If everything else fails – fall back option to national roaming onto public, commercial (LTE) networks.

As can be inferred from the incomplete list above, public, commercial networks are generally neither engineered nor maintained to the strictest standards that should ideally be applied to public safety network design and

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[13] Distributed antenna systems.

[14] An end-user terminal connected to the network can serve as a relay node for end-user terminals that are (temporarily) beyond the reach of the network.

[15] Mean Time To Repair. A short MTTR is essential to warrant high system availability, especially so in non-redundant system architectures.

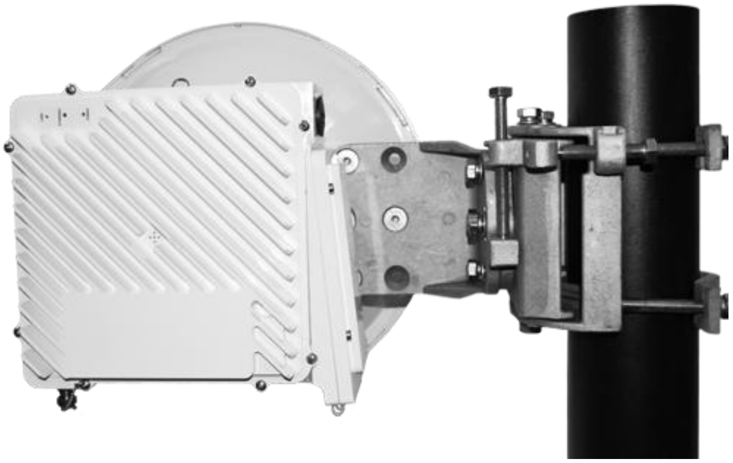
maintenance, because living up to those elevated standards inevitably comes at a cost. That extra cost is not justifiable in a mainstream commercial network where the primary benchmarks are Return on Investment, Average Revenue per User and subscriber churn, and not full geographical coverage and a near 100% service availability. However, a good starting point to consider may often be to augment and add to an existing commercial mobile network to make it suitable for public safety applications, while leveraging the existing network asset.

MICROWAVE RADIO FOR WIRELESS PUBLIC SAFETY NETWORKS

Microwave radio technology has found its way into public safety networks, providing data backhaul services for wireless applications like TETRA and P25.

Rapid deployment capability and an acceptable total cost of ownership are clearly important attributes for any backhaul technology supporting any wireless network. But more is needed to support next-generation broadband wireless public safety networks. Additional important requirements that are to be fulfilled by microwave radio backhaul:

1. Deployable in harsh environmental conditions, in an unprotected outdoor environment,
2. High service availability ≥99.995%, provided by high equipment availability, topological redundancy and/or link hardware redundancy,
3. Low link latency; 0.1-1 ms per link,
4. High link bandwidth; up to and beyond 200 Mbps per wireless base station site,
5. Support for frequency *and* phase synchronization in cases where a TDD or 4.5G-based technology (e.g. LTE-Advanced) is used for the radio access,
6. Network resilience; no “single point of failure” in *any* vital part of the network; geographical redundancy for centralized network functions,
7. A high degree of network integrity and data confidentiality, through (user) authentication and payload encryption.



DragonWave’s Harmony Enhanced – capable of delivering between 1 and 2 Gbps across a link in a 112 MHz channel in a simple 1+0 configuration – and featuring a 4-port 14 Gbps non-blocking switch.

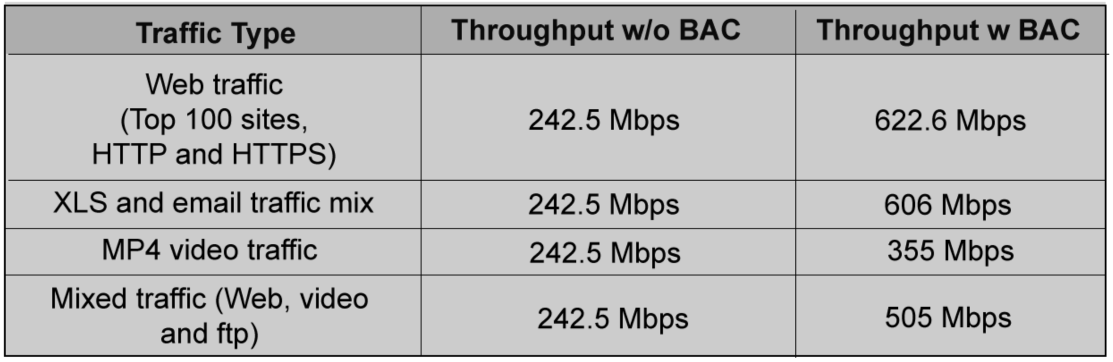
MICROWAVE RADIO – THE IDEAL BACHAUL ENGINE FOR PUBLIC SAFETY NETWORKS

The third generation of rugged, all-outdoor, ultrahigh-capacity packet microwave radio is the ideal backhaul engine for next-generation broadband wireless public safety networks, because:

1. All payload generated by a broadband wireless network is by default packet-based. There's no need for circuit emulation or deployment of hybrid systems. High capacity Gigabit Ethernet (GE) or even 10 Gigabit Ethernet (10GE) interfaces substitute a very large number of narrowband, legacy PDH and SDH/SONET interfaces.

2. No shelters at all are needed for backhaul equipment. Third-generation packet microwave radios are rugged, all-outdoor systems with four GE interfaces, plus a potent multi-gigabit Ethernet switch (14+ Gbps), in a single, integrated system. It disposes of traditional split-mount system indoor units and cell-site routers, freeing up space and budgets.

3. They provide high base-line spectral efficiency, in the order of 8 bps/Hz using 2048 QAM or 4096 QAM modulation. Spectral efficiency can be doubled to 16 bps/Hz by deploying 2x2 Line of Sight (LoS) MIMO[16] or 2+0 XPIC[17]. Beyond that, there's the possibility to boost spectral efficiency to >32 bps/Hz by deploying wire-speed bulk data compression. Spectral efficiency reduces operational expenditure by paring down channel size and spectrum lease cost or provides for additional traffic capability.



Traffic Type	Throughput w/o BAC	Throughput w BAC
Web traffic (Top 100 sites, HTTP and HTTPS)	242.5 Mbps	622.6 Mbps
XLS and email traffic mix	242.5 Mbps	606 Mbps
MP4 video traffic	242.5 Mbps	355 Mbps
Mixed traffic (Web, video and ftp)	242.5 Mbps	505 Mbps

Example of how throughput in a 28 MHz channel can be increased by applying bulk compression

4. They support large channel size. Large channels help support scenarios where very high throughputs are required for trunking purposes. Third-generation all-outdoor packet microwave radios support 100 (ANSI) and 112 (ETSI) MHz channels. In case even more capacity is required, multicarrier microwave

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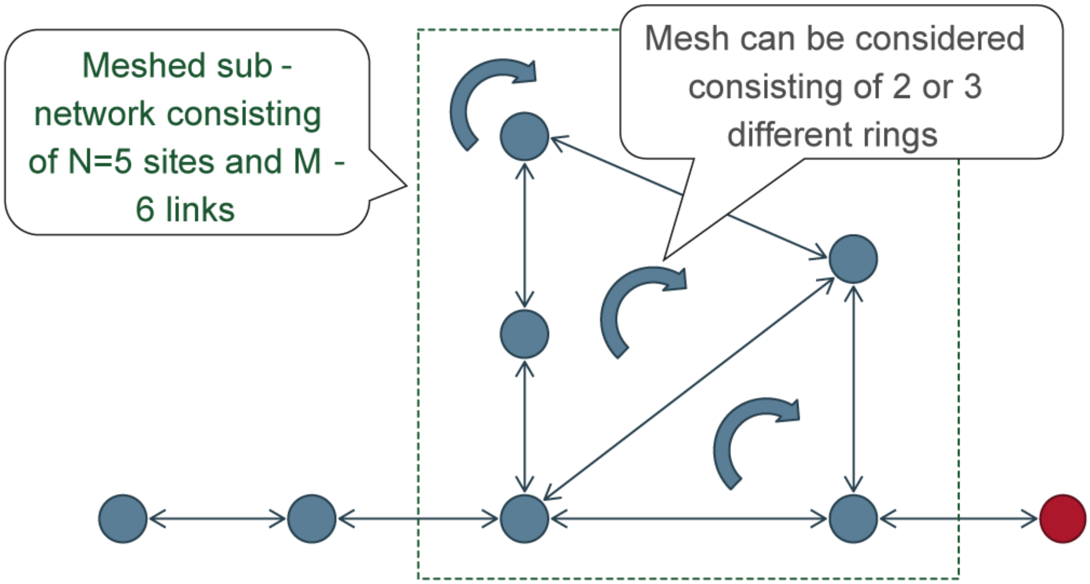
[16] Multiple Input Multiple Output; a radio frequency scheme where multiple transmitters and receivers (with a minimum of 2) are used at each end of a link to increase the link spectral efficiency of a single (polarization) radio channel by up to 100%, or to increase link budget by up to 9 dB (in 2x2 MIMO case)

[17] Cross-Polarization Interference Cancellation; a radio frequency interference cancellation scheme enabling the use of a single radio channel in two spatially orthogonal polarizations, in order to double link throughput and, in a way, spectral efficiency.

radio variants are available as a cost-effective alternative to discrete 2+0 and 4 x 4 MIMO configurations.

5. Full support for equipment *and* topological redundancy leading to link availability in excess of 99.999% and to network resiliency on the macro level. Equipment redundancy means that every link can be configured with no single point of equipment failure. Topological redundancy is implemented by building a network *topology* that can maintain connectivity between key network points A and B through different *physical* data paths. If one path is cut, one or more alternative paths exist. Third generation all-outdoor microwave radio equipment supports this through the implementation of redundancy protocols like RSTP, MSTP[18], protecting against multiple simultaneous failures yet relatively slowly – (200-2000 ms) or G.8031 (Ethernet Linear Protection) and G.8032 (Ethernet Ring Protection) – while protecting against a single failure yet very fast (< 50 ms).



The network inside the green dotted box can be protected topologically. A single link failure will not affect any site; a single site failure won't affect any other site.

6. Low latency. Microwave radio links featuring high spectral efficiency and capacity provide for lower link latency than less efficient, slower links. Third-generation all-outdoor packet microwave systems can have latencies as low as 0.1 ms. Mobile broadband system-inherent latency is in the order of 10-15 ms one-way end-to end and the contribution of third generation microwave systems to the overall latency is very limited. Full system performance is warranted when using such microwave links for backhaul.

7. Comprehensive synchronization support. Third-generation all-outdoor packet microwave systems support frequency synchronization though Synchronous Ethernet and frequency *and* phase synchronization. This is achieved by treating IEEE1588v2 synchronization packets with the highest priority in their queueing system and minimizing jitter by means of packet cut-through for highest-priority

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[18] Rapid Spanning Tree Protocol and Multiple Spanning Tree Protocol

packets. In addition, phase synchronization accuracy is improved by means of a Transparent Clock, an algorithm compensating for microwave link-induced jitter and latency. Phase synchronization is required for synchronizing TDD-based wireless access technologies and for advanced 4.5G features requiring phase lock of the wireless air interface across the entire network.

8. Strong support of network integrity and data confidentiality. Third-generation all-outdoor packet microwave systems support SNMPv3 for full encryption of the management plane for the microwave system. They also support centralized RADIUS and TACACS+ user authentication. On top of this, all payload transiting the air interface can be AES256 encrypted. In addition, end-to-end authentication and encryption schemes, like for instance IPSec, are supported.

CONCLUSION

Wireless public safety networks are evolving towards supporting mobile broadband services, most likely based on 3GPP LTE standards (Rel. 13) while maintaining the very high service availability and data security standards of today’s voice-centric networks.

Third generation rugged, all-outdoor, ultrahigh-capacity packet microwave radio is ideally suited as the main backhaul engine for broadband wireless public safety network, because of its very modest total cost of ownership, quick and easy outdoor deployment and excellent technical attributes tailored towards supporting 4G and 4.5G wireless access networks.