US Advanced Railroad Wireless (ARW)

Using PTC as a foundation for ARW

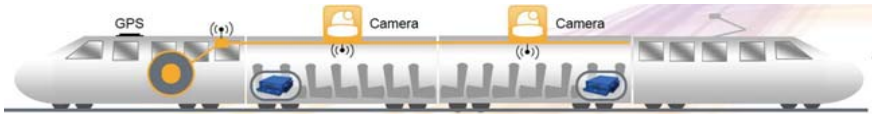
January 2014 - V2

SkyTel - W. Havens

"SkyTel" means Skybridge Spectrum Foundation, Telesaurus Holdings GB LLC, Environmentel LLC, Verde Systems LLC, Intelligent Transportation …LLC, and V2G LLC. Warren Havens is President of these companies.

This partial, public version is filed in FCC docket 11-79, January _ , 2014.

This is filed in this docket for purposes stated by the FCC, and in response to recent ex parte presentations by some railroads' that implicate SkyTel, SkyTel's ATMS licenses, our offers of AMTS spectrum to railroads, and the public interest the FCC indicates in opening and conducting this docket.



Credit: Nokia Siemens

The *SKYTEL* group holds a broad, unique assembly of radio spectrum in the *900, 200 & 40 MHz* ranges nationwide, listed in *Section 6* below, as the *foundation** for nationwide wireless for smart transport, energy and environment systems, with high-accuracy PNT* (which we call "*Terranautics*") in public-private-nonprofit partnerships.

Advanced Railroad Wireless (ARW), outlined herein, is within *Terranautics*.

This PPT illustrates components and benefits of Terranautics, not only of ARW.

*7 SPECTRUM: ENABLER AND LIFEBLOOD

The availability (or not) of adequate RF spectrum in appropriate bands, and suitably clear of other services or interfering signals, is a fundamental precondition to implementing any new radio technology for any application. LTE is no different in this respect to those technologies that have come before it, or indeed those that may eventually supersede it. Spectrum is truly the enabler and lifeblood of any new system coming to market, and it is a distinctly scarce and finite resource globally.

p3 communications | LTE for Critical Communications
Drivers, Benefits and Challenges

Above excerpts is from the publication listed above, copy at:
http://www.p3-group.com/downloads/4/1/7/5/2012-06_P3_-_LTE_for_Critical_Communications_-_White_Paper_-_v2_0.pdf

*" Position, Navigation and Timing," as used in the GNSS/ radiolocation industry.

Contents

(i) PTC background: Bad benefits/cost, tech and excuses. Good as platform for AWR.

1. *Corridor* ARW plan (NEC used as example) is sane, but a plan with independent railroad wireless systems and spectrum is severely wasteful, and hardly possible with available spectrum and public funding.
2. *Wideband* contiguous spectrum and benefits, including in 200 MHz.
3. *High Accuracy Location* (HALO) with one-way Broadcast data, for "RCAS" - Railroad Collision Avoidance Systems (i) makes PTC *redundant*, and (ii) is, by an order or magnitude or more, more cost effective to deploy and maintain, and is needed anyway for ARW.
4. *Advanced Railroad Wireless* (ARW-CW-HALO) (ARW for Corridors with Wideband and High Accuracy Location).
5. *Security*. Deficiencies in one -band, one -mode PTC systems vs. multi-mode ARW.
6. *Spectrum* licenses of SkyTel entities: 217-220, 904-910+, 35/43 MHz, and SkyTel.
   - SkyTel obtained these for nationwide smart transport, energy and environment systems, which can include *ARW*.
   - Persons too fixed on PTC are not in a position to consider or pursue *ARW*, as we experience. It may even be seen (falsely) as a threat.
   - We present *ARW* as part of our nationwide plans, including to persons in various federal agencies Congress, and other public entities. Public-private-nonprofit (all 3 sectors) are best combination.

- (i) –

PTC background:

Bad benefits/cost, tech and excuses.

Good as platform for AWR.

PUBLIC LAW 110–432—OCT. 16, 2008 The "Rail Safety Improvement Act of 2008"

"(3) POSITIVE TRAIN CONTROL SYSTEM.—The term 'positive train control system' means a system designed to prevent train-to-train collisions, over-speed derailments, incursions into established work zone limits, and the movement of a train through a switch left in the wrong position.".

PTC is not a wireless spectrum band, technology or system.

It is not necessarily a two-way wireless system.

It does not have to be in, or only in 220-MHz range spectrum.

It does not have to be a stand-alone wireless application.

It does not have to be what the freight railroads want and promote it to be.

It does not have to be wasteful and ignorant of the best spectrum, tech, and systems available, with only simple objective assessment, free of undue special interests and personal buy-ins to what is, thus far, deficient PTC-only plans.

It does not have to make US railroad / government wireless into a laughing stock internationally and internally among the non-deluded, which will eventually be clear.

PTC since 2008, PTC radio systems, asserted spectrum shortage, etc.

SkyTel presented on PTC in FCC docket 11-79. Those and easily accessible public materials and research show:

- *PTC wireless does not need much spectrum. There is little data to be passed.*
- *There is no PTC wireless system plan of substance to date with essential components, including defined security, applications, grades of service, data capacity needed, wireless coverage and capacity needed, types of radio tech to be used, spectrum needed, system and architecture alternatives, etc.** Not surprisingly, railroads do not seek radio equipment that make sense- for wider channels and spectrum efficiencies.*
- *Railroads were mandated to implement PTC, by a general Congressional Act, but it is an unfunded mandate [see End Note 1- last section] that is resisted. Assertions of lack of radio spectrum is one means to resist …*
- *… at least to slow implementation, and in the delay, seek funding, etc. SkyTel entities have a plurality of 217-222 MHz available for PTC, but not once has any railroad responded to our initiated proposals over many years. Some railroad have issued to Skytel requests for information, interest, and not-fully-defined proposals. SkyTel has always responded.** (We have, at times, offered spectrum at little or no financial cost (and only modest other cost, clearly in the public interest), or at appraised value less a discount, and in any case never above fair market value (which we know: all sales of geographic AMTS spectrum have been directly by us, of our spectrum).*
- *These assertions are for the most part false. SkyTel can provide details to the FCC (some public, and some confidential), if the FCC would like to have them, to compare to assertions of some railroads.*
- * E.g., not one railroad has, in public (per our substantial research), or in private communications with us, reflected basic knowledge of fundamental major differences in many of these factors, e.g., the major difference in performance per amount of spectrum by use of a large spectrum block vs. separated narrow channels, and use of modern wider band technologies. Some of this is discussed below.
- *** SkyTel's responses are timely and well within the fair market in economic terms, contract language, etc.: If railroads had current* interest and capability (funds, authority, a serious PTC plan, etc.), the FCC would have seen assignments or leases. *Our conclusion is that the public agency railroads in this case are not yet "ready buyers" in a "market" situation. This appears to be since there is a Government to Government fight (federal vs. state-local), and that does not support a proper market environment (the "market" is not G to G).*

Re: PTC since 2008, PTC radio systems, asserted spectrum shortage, etc. (continued)

As indicated on the preceding page, in our substantial experience with PTC wireless and public agency railroads, the railroads are subject to an expensive, burdensome, unfunded mandate. See also the last page below – Endnotes.

PTC wireless by itself does not make sense. This is plain now, and will come to haunt those who avoid.

*But what makes sense is **Advanced Railroad Wireless (ARW)**, that leverages the mandated PTC, to provide an order of magnitude- plus in improvements over PTC in applications, security, capacity, future viability, benefits-to-cost, integration with commercial wireless on trains, etc.*

We present ARW below. Some form of "ARW" (by various names) is being implemented worldwide. The US should not get further behind. It is actually in a good position to lead.

This PTC fixation is a diversion -- but it can be used as a platform for ARW.

ARW will use highly spectrum efficient tech, systems and architecture. These are currently available.

It may end up fully covering costs, resulting in NO NET COSTS to government railroads.

The radio frequency band to be used for communication must be known prior to equipment purchases. PTC-220 LLC, a consortium of the Union Pacific, Norfolk Southern, CSX, and BNSF railroads, has purchased licenses to some frequencies in the 220 MHz range,[35] and is requesting the Federal Communications Commission (FCC) to reassign additional spectrum in the 220 MHz band to the railroads for the purpose of PTC. The FCC has designated spectrum in the 220 MHz range mainly for commercial uses and has auctioned licenses to various parties. [1]

Furthermore, along with Amtrak and other railroads, the consortium has requested additional 217-222 MHz spectrum and appropriate license and rule changes, claiming 220 MHz will be insufficient in congested areas.[36] Although frequencies may be available in various bands, the railroads prefer the 217-222 MHz range due to compatibility with current infrastructure and the radio communication technology they have chosen to employ (I-ETMS).[37] Because of uncertainty over spectrum needs, the FCC issued a public notice seeking comments from stakeholders on May 5, 2011, but has not instituted a formal rulemaking process regarding PTC radio spectrum issues.[38] [2]

The railroads' requests for dedicated spectrum for PTC raise a number of policy issues. Licenses to much of the spectrum requested by the railroads have been purchased by other entities in FCC auctions. While the FCC is empowered to reallocate spectrum if necessary for public safety, reassignment for PTC would effectively represent a forced transfer of licenses from some private parties to others. In comments submitted to the FCC, some current licensees of spectrum in the 218-219 MHz range asserted that it is unfair to reallocate spectrum to which they have purchased rights in a competitive bidding process. They also believe the railroads have identified 220 MHz as the core spectrum for PTC without sufficient investigation into their specific radio communication needs or possible alternatives. They contend the railroads can lease spectrum from primary license holders without FCC action.[39] [3]

The railroads counter that leasing spectrum for PTC from existing license holders could raise their costs by creating captive demand for a limited amount of spectrum. A related problem stems from the fact that some of the railroads required to install PTC are commuter lines owned by state or local government agencies. These agencies may have difficulty raising the funds to obtain desirable frequencies in competitive auctions; indeed, the FCC normally assigns frequencies to government agencies at no cost. [4]

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[36] Association of American Railroads, *Comments of Association of American Railroads*, Federal Communications Commission, WT Docket No. 11-79, June 20, 2011, http://apps.fcc.gov/ecfs/document/view?id=7021688770.

[37] It should be noted that the radio communication supplier for ETMS is MeteorComm, a wholly owned subsidiary of BNSF, and BNSF is a member of PTC-220, LLC. MeteorComm, "MeteorComm™ Powers BNSF's Electronic Train Management Communications," press release, January 19, 2007, http://meteorcomm.com/downloads/MCC_PSPApproval.pdf.

[38] Federal Communications Commission, Wireless Telecommunications Bureau Seeks Comment on Spectrum Needs for the Implementation of the Positive Train Control Provisions of the Rail Safety Improvement Act of 2008, WT Docket No. 11-79, Washington, D.C., May 5, 2011, http://fjallfoss.fcc.gov/edocs_public/attachmatch/DA-11-838A1.pdf.

[39] The Coalition of 218-219 MHz Service Licensees, *Reply Comments of The Coalition of 218-219 MHz Licensees*, Federal Communications Commission, WT Docket No. 11-79, July 11, 2011, http://apps.fcc.gov/ecfs//document/view.action?id=7021691731.

http://www.purdue.edu/research/gpri/publications/documents/Peters_CRS_Report.pdf

Congressional Research Service

Positive Train Control (PTC): Overview and Policy Issues

Jeffrey C. Peters
Research Associate

July 30, 2012

John Frittelli
Specialist in Transportation Policy

- The text on left is from this CRS report from mostly second hand sources.
- The authors did not contact SkyTel and would not respond to W. Havens.

SkyTel believes assertions on the left are wrong and reveal lack of candor with the FCC and Congress:

[1] [2] These railroads *show no need* for PTC spectrum- they got their 220 MHz and want more, for their non-PTC profit business. They failed to show otherwise in the PTC docket, the related SCRRA docket, and their own special construction-waiver proceeding.

[3] [4] SkyTel did not assert it was "unfair," but that it would be illegal, at least without proper eminent domain procedure, but for that, the railroads have to show a compelling need, and they have not done that– their allegations of spectrum problems is used to object to and delay PTC mandate, try to find money, etc. Railroads at the same time– (i) threaten SkyTel and other spectrum licensees in this way ("we need to take you licenses by "reallocation" or else we will run over grandma…") and (ii) "negotiate" for spectrum as if in the "fair market," and at the same time (a) say they *indeed have billions* of dollars they are raising and committing for PTC (alleged associated large system integrator contracts, etc.) but (b) then lament to the FCC that they *indeed have scant* money for spectrum.

SkyTel has not once had a problem agreeing on price and terms with power utilities and others that actually seek spectrum at fair market terms and conditions. SkyTel had not raised prices for any railroads, verses its appraised fair market prices and formulas. The problem is– understandably— the railoads do not want the PTC boondogle. It should be switched to Advanced Railroad Wireless.

None of the results for "positive train control," "PTC" and related terms presents or hints at PTC Plan as outlined on the preceding page (including the paper from Meteorcomm and papers regarding IEEE 802.15 fir PTC).

This IEEE database has extensive articles on all actually planned, viable wireless technologies and systems – BUT NOT US PTC. IEEE members can verify the above assertion in detail, and without being a member you can search and get abstracts.

High-Accuracy Mandate

The U.S. Rail Safety Improvement Act of 2008 that passed shortly after the deadly commuter rail accident in Los Angeles mandates a whole new level of positional accuracy in order to improve rail transportation automation. The federal rail safety program for Positive Train Control (PTC) on the Class 1 freight rails in North America mandates that each train be tracked, and that no trains may travel on a track without its location being known.

There are significant technological hurdles for the railways to address before compliance with PTC becomes mandatory in 2015. The requirements of the system are to prevent an over-speed through automated engine controls, to avoid signal violations, to protect track crews, to prevent movement through a switch even if it is in the wrong position, and to know the location of every rail asset within 2.2 meters of horizontal accuracy and 0.8 meters vertical.

These excerpts in blue boxes are from: Trimble "Accuracy in the Workforce," May 2011.

Achieving the location requirement is a difficult task given that the accuracy requirement is below today's mapping-grade GPS, and the PTC requirement specifies that the location of all assets must be maintained to 100% accuracy at all times.

SkyTel has not yet confirmed Trimble's specific assertions here in law, but generally high accuracy location ("HALO" - see Section 3 below) is needed for train (and all roadway vehicular) safety and efficiency, and critical infrastructure asset inventories. For HALO, (i) the roadway must be precisely surveyed and mapped in digital GIS, and (ii) the moving vehicles must be tracked in real time in differential GPS-GNSS with ongoing error corrections. "Network RTK" is being adopted worldwide for Intelligent Vehicle Transportation Systems, as the most accurate and very cost effective HALO for roadways. Thus can include railroads as well as non-rail roadways.

- 1 –

Corridor ARW plan
(NEC used as example)

Corridor ARW is practical & efficient,

but any PTC-only plan, or any other plan

with independent railroad wireless systems & spectrum

is severely wasteful,

and not possible with available spectrum & public funding.

US Corridor ARW:

First, it is *not PTC* - but will *easily provide PTC* as a simple application. It will use PTC and 220 MHz range spectrum better and expand for needed viability.

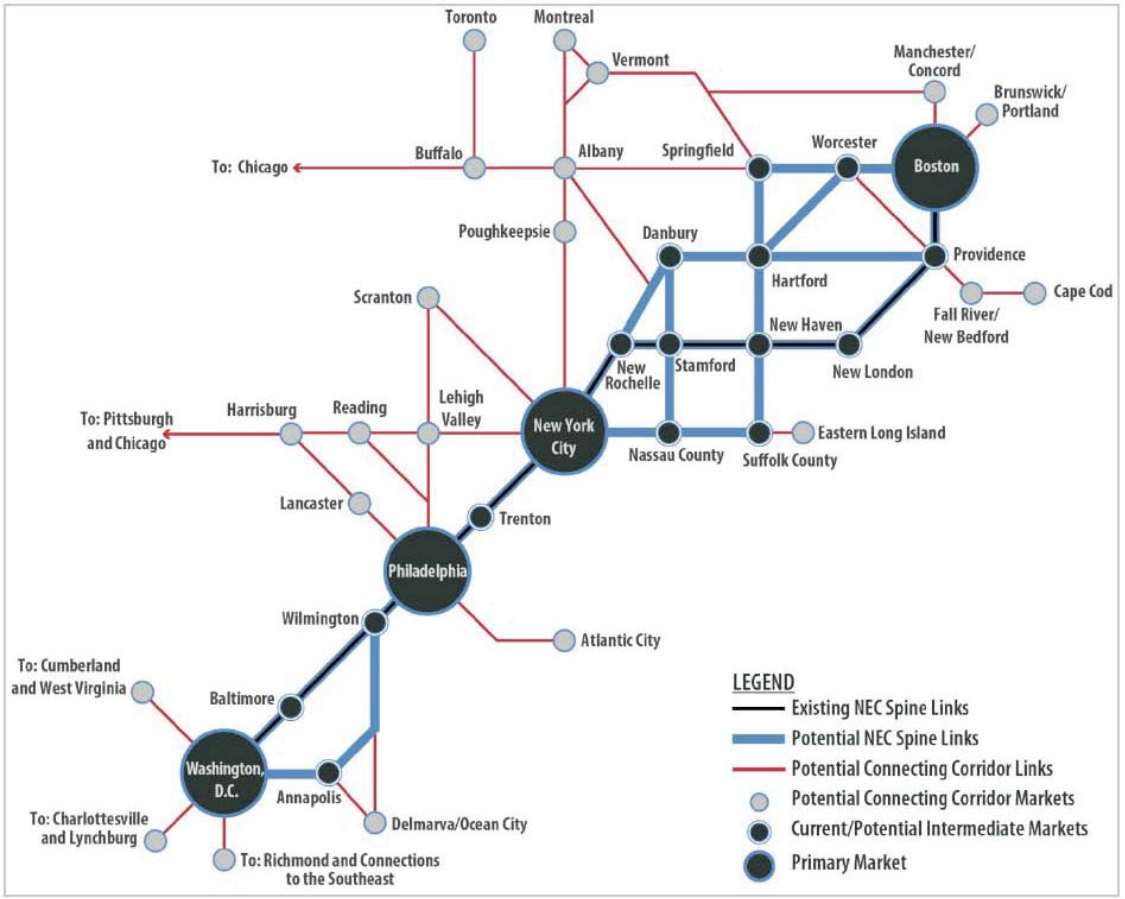
What is the PTC wireless plan after 5 years from the Metrolink accident ?

There is no PTC wireless plan: no real plan with essential components, including defined applications, grades of service, data capacity needed, resultant wireless coverage and capacity needed, types of radio tech to be used, spectrum needed, system and architecture alternatives, etc.

Don't believe it - *go try to find one*. Not presented by any railroad, PTC radio equipment provide, systems integrator, FRA, APTA, AAR; not on Internet, not in FCC 11-79, not under *IEEE* (see preceding page), etc. *This PTC emperor has no clothes*. PTC is not wanted as it is bad law, bad cost/benefit = no plan, but a lot of effort to extend the deadline, and figure out how *the public* will pay for this *PTCon boondogle*.

The rest of the developed world has plans and implementations for advanced railroad wireless, to include PTC functions. The US is diverted by PTC Congress demands and the railroads do not want to do. Implementing Advanced Railroad Wireless in the US can turn PTC into the best ARW in the world.

Figure 6: Initial Alternatives Networks for NEC Spine and Connecting Corridors



We use this to illustrate *the need for* Corridor wireless systems, plans, and spectrum for US passenger railroads.

If each segment of this NEC *or any* railroad corridor with multiple segments (operated by different railroads or otherwise), has *its own* system and spectrum, *there is great waste* of spectrum, and system capital and operating costs, and less security, inter-segment interoperability, less economies of scale in equipment used, etc. (We continue and demonstrate this below.)

In addition, Skytel proposes for this NEC Rail Corridor - Advanced Railroad Wireless, on *Corridor* basis, with *Wideband* spectrum and equipment in 217-220 MHz, 904-910 MHz & 35-43 MHz. This should be *supported at the federal level* as is this NEC Future Rail Investment Plan.

USDOT, Federal Railroad Administration, Office of Railroad Policy & Development. http://necfuture.com/pdfs/prelim_alts_report.pdf

Congressional Research Service

Positive Train Control (PTC): Overview and Policy Issues

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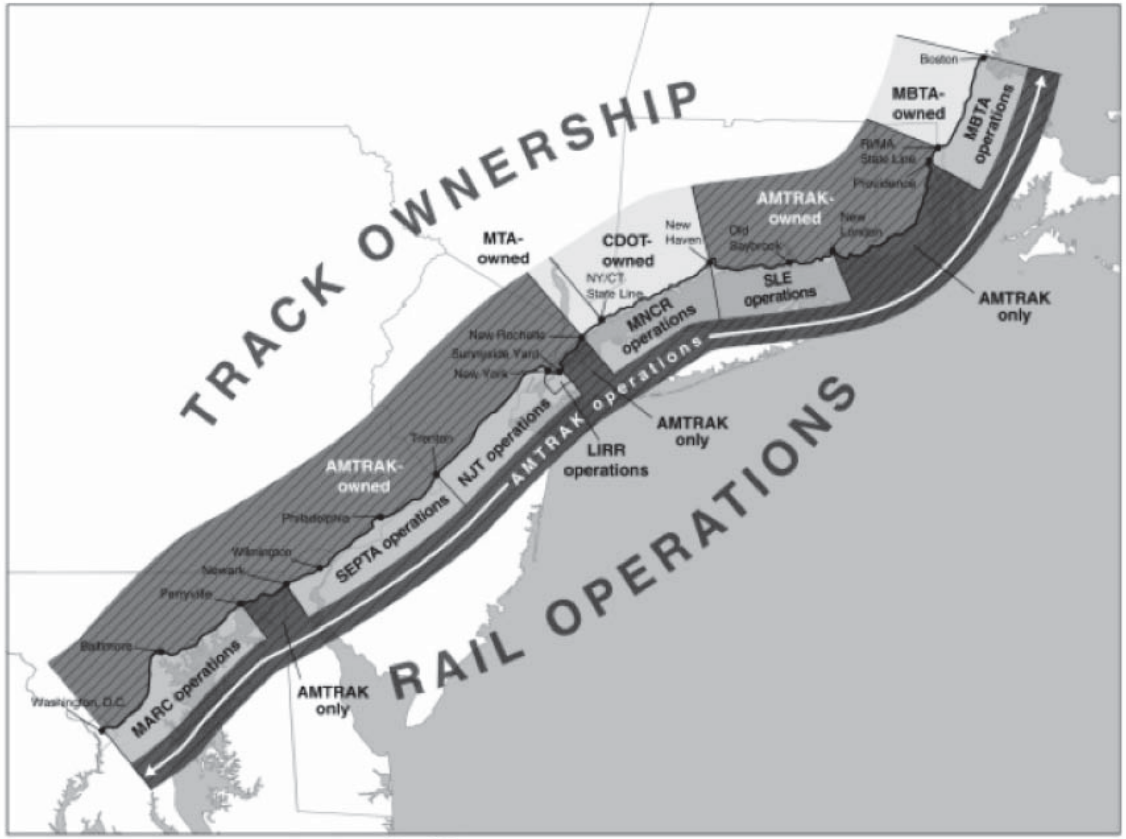
July 30, 2012

Figure 4. Track Ownership and Rail Operations in the Northeast Corridor



Source: Government Accountability Office, GAO—06-470, *Commuter Rail Issues Should Be Considered in Debate Over Amtrak*, April 2006.

http://www.purdue.edu/research/gpri/publications/documents/Peters_CRS_Report.pdf

This shows the *per-railroad segments* along NEC (passenger rail operations). There should be *one NEC Advanced Railroad Wireless system*.

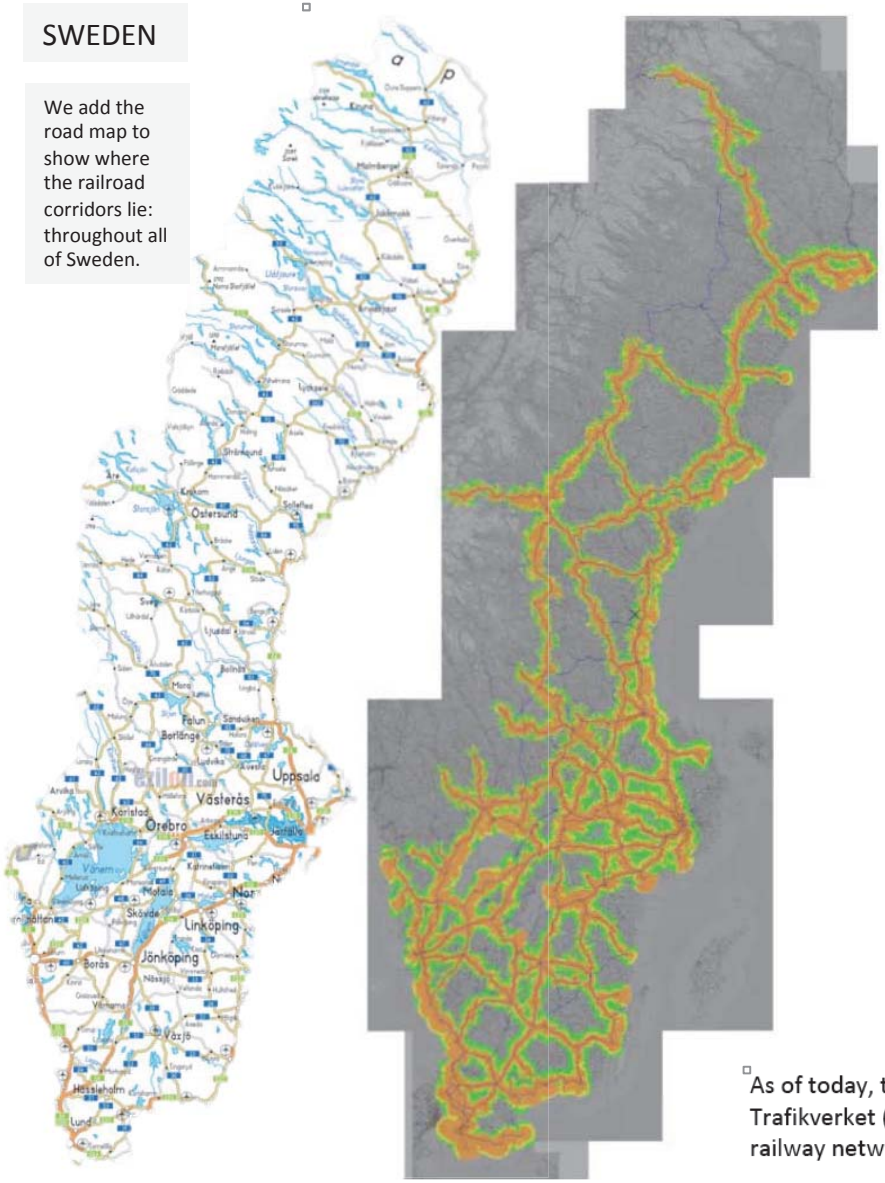
That is best served by *one, integrated spectrum plan* that supports the best radio tech, equipment and systems, as we propose herein. *Spectrum is the foundation*. (Try to show otherwise.)

NEC ARW should use wideband spectrum and tech, and support: (i) first, train operations, but also (ii) passenger broadband – underlying 4G LTE commercial wireless and WiFi, and making the passenger wireless highly reliable -- with no coverage gaps (more below).

Citizen users and taxpayers should get the best, and best benefits/costs NEC railroad system – this needs ARW as we propose herein. This can only be achieved with federal level leadership and support.

SWEDEN

We add the road map to show where the railroad corridors lie: throughout all of Sweden.



Coexistence between GSM-R and 3G / 4G-Systems in the 900 MHz Frequency Band - Swedish View. TRV 2013/13976 1 March 2013

http://www.trafikverket.se/PageFiles/117321/coexistence.pdf

EXAMPLE. From the document listed above, this is a map of the nationwide Swedish 900 MHz GSM-R (GSM for Railroads) radio system. It uses a *block* of *900 MHz* spectrum adjacent to the commercial GSM 900 MHz spectrum Tx and Rx bands. On all rail corridors, even in rugged parts of Sweden, *the radio-paths are fully known*, and reliable coverage is easy to plan and implement. *900 MHz serves well*,* and there is not sufficient VHF in any developed nation for substantial advanced railroad wireless.

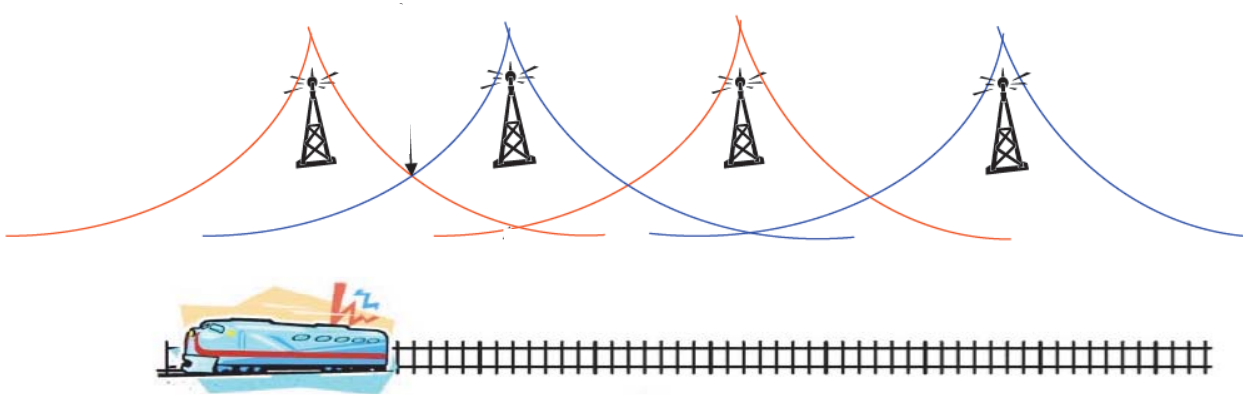
If this depicted system had to use the same spectrum in segments, where the inter-segment spectrum use *was not coordinated* (causing co-channel interference, and thus large distances for mitigation of that interference) then approximately *DOUBLE* the amount of spectrum would be needed. *The converse applies: the same spectrum can be used on all segments if coordinated.* Further, *if* the depicted system used *non-adjacent* spectrum of small per-channel bandwidth, with other entities using the interleaved spectrum, then each channel would need substantial adjacent-channel-interference guard-band spectrum, to leave vacant, that could *further ~ DOUBLE* the spectrum needed *for same coverage capacity*. [Re an even greater increase - see p. below.]

BUT this waste is what US railroads along a corridor, e.g., the NEC plan for PTC: Use of *non-coordinated* spectrum along different segments of different railroads, and use of *non-adjacent narrow* channels. It *shows lack of the fundamental knowledge and care* in spectrum and system planning, and lack of awareness of other advantages of wide-band spectrum, technology, radios and systems.

As of today, the Swedish GSM-R system MobiSIR is implemented on all lines administered by Trafikverket (10 000 km) and at Inlandsbanan (700 km, last 300 km under construction), the railway network consists of approximately 1 200 base stations and 350 repeaters.

Figure 1: Coverage map for the Swedish GSM-R system MobiSIR (January 2013)

* But 200/ 900 / 40 MHz is far better, as we propose.



Depiction: Red and Blue represent different narrow channels, rather than using the same total amount of spectrum at each base station antenna site.

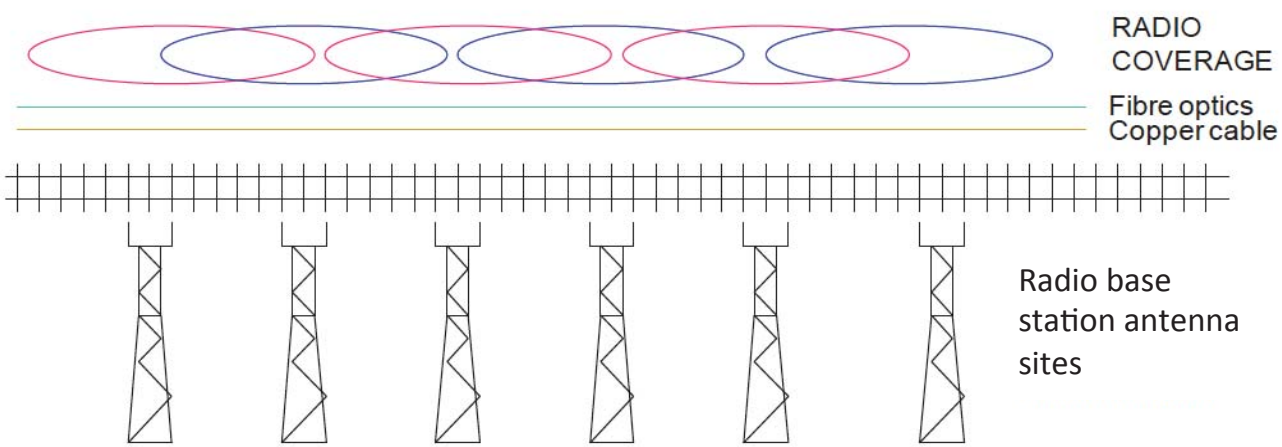
Height of red/ blue lines represents Effective Radiated Power.

1. Use of the same wider channels at each site, with appropriate technology (in part discussed below) is *far* more spectrum efficient. *First*, the technology is more spectrum efficient. But more fundamental –

2. *Second*, it allows *all* of the *spectrum* to be used at each site and *each length of the track*, as the trains pass.* Use of different spectrum per segment of track makes no sense – it only makes sense, sometimes (such as in days past, when wideband wireless was not viable) in wide-area all-directions wireless, such as covering large land masses with roads and users in all directions. *Trains corridors are not like that*: even in urban areas with train corridors sometimes crossing, multiple trains are generally not in the area of one base station at the same time. *Spectrum should be fully allocated when a use arises (here, when a train passes), then fully allocated down the track at another station when the use arises.*

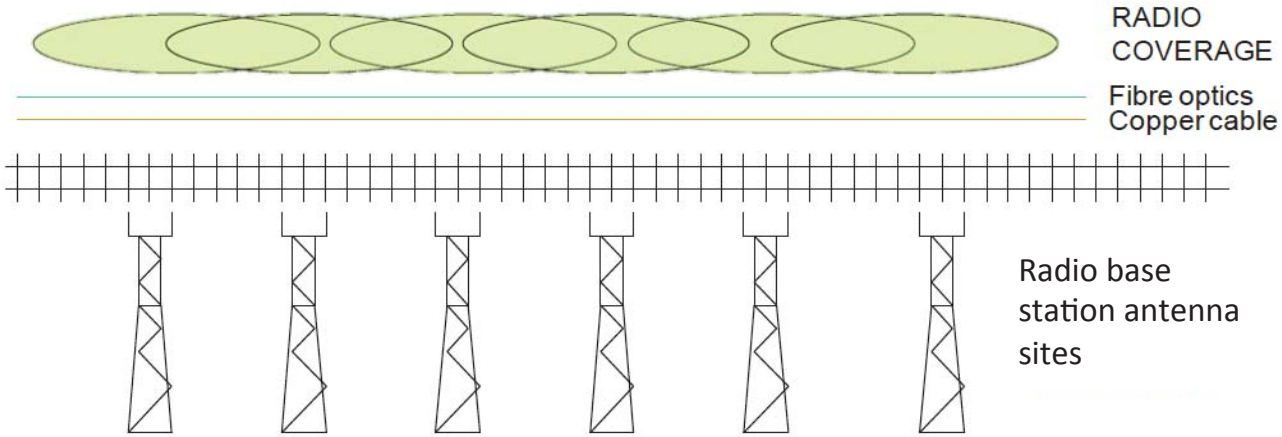
3. *Third*, use of non-contiguous more-narrow channels at adjacent sites along a railroad corridor requires a guard band (built into the channel, or beyond the channel) – per each channel – which is spectrum inefficient verses use of the wider channels. (This is shown in a slide below.)

* It allows close to this even when there are no trains – which raises the question: How to use this extra capacity? It can be used for other mission-critical functions, *and substantially underwrite / reduce the railroad-use cost.*



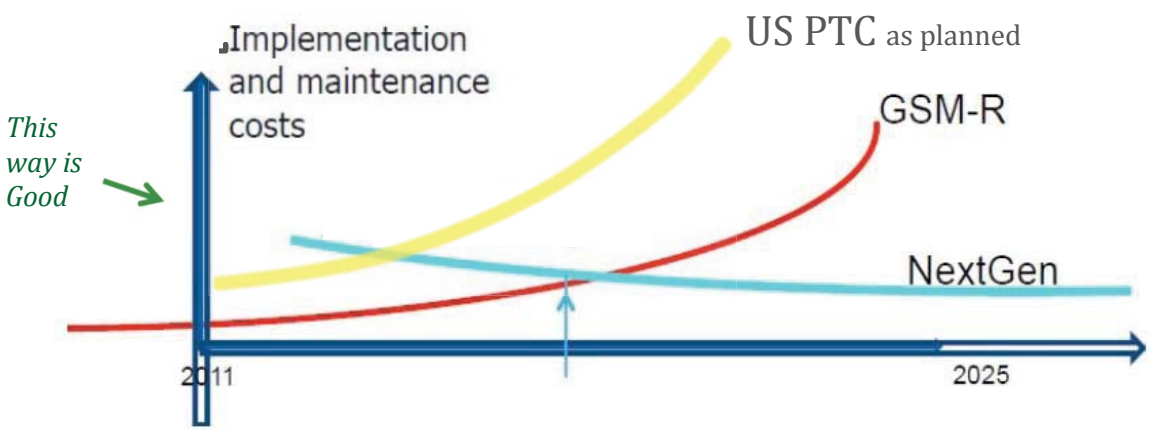
Depiction: see preceding page:

Red and Blue represent different narrow channels, rather than using the same total amount of spectrum at each base station antenna site.



The **light green-yellow** in all of the depicted "cell site" radio-coverage areas, along the train corridor, represent the *SAME WIDE BAND* channel used at each site, in each coverage area.*

* *See preceding page as to initial summary of some of the benefits.*



http://www.diva-portal.org/smash/get/diva2:644985/FULLTEXT01.pdf
(SkyTel added to the above the curve and label on US PTC as planned, and which was is good.)

"NextGen" LTE and LTE-like tech and systems provide the benefits in part summarized above: use of *wide band* channels, *all used at each base station* ("cell site" "antenna site," "eNodeB" – all meaning the same).

On on analysis of Costs/Benefits (benefits being: system capacity, reliability, applications serviced, future viability, etc.), the above curves would be even more in favor of the "NextGen" which herein we called *Advanced Railroad Wireless*, especially since we propose three spectrum bands, and both two-way and one-way wireless, which affords major advantages.

GSM-R is a 2nd Gen commercial land mobile wireless technology. It is reasonable spectrum & cost efficient (capital & operating costs). *US PTC* wireless is far less spectrum and cost efficient vs GSM-R.

LTE and LTE-like tech & systems for railroad is far more spectrum and cost efficient vs. GSM-R as depicted here (spectrum is part of overall costs, when it is even available), and some *order(s) of magnitude more spectrum and cost efficient vs. US planned PTC wireless.*

But beyond that, *planned US PTC wireless will simply not meet the needed applications for train and passenger safety and other critical functions. IT is an artificial federal imposition. Federal agencies can turn it into major win, via support of Advanced Railroad Wireless.*

US PTC as planned

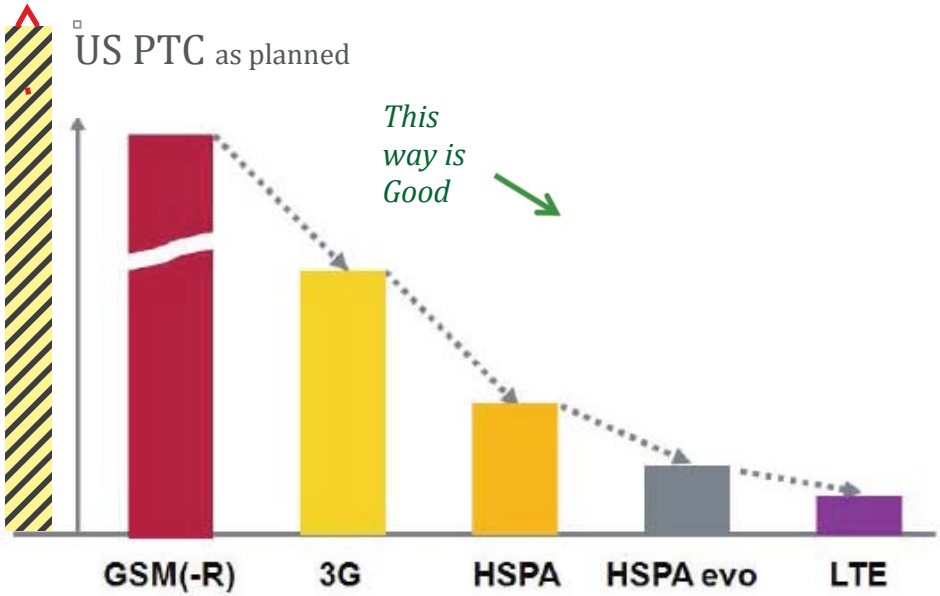


Figure 4.4: Cost Per Mbyte comparison. [24]

This expands upon the points commenced on the preceding pages.

http://www.diva-portal.org/smash/get/diva2:644985/FULLTEXT01.pdf

(SkyTel added to the above the bar and label on US PTC as planned, and which way is good.)

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RAILWAYS COMMUNICATIONS E-ZINE

http://www2.alcatel-lucent.com/blogs/tracktalk/issue-5/planning-is-vital-to-unlock-the-full-potential-of-lte/

Planning is vital to unlock the full potential of LTE

By: Olivier Andre, Transportation Market Leader • **Issue:** Unleashing 4G - Understanding how railway communications will look tomorrow, today • **Category:** Expert View

This expands upon the points commenced on the preceding pages.

Highlights

- IP-based networks will bring greater flexibility and reliability to railway telecoms
- Enhanced onboard communications can give rail a competitive edge over other modes
- Spectrum availability is an issue the industry needs to focus on today
- Metros and mainline railways will take different routes to LTE deployment

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Consolidating networks delivers a step-change in efficiency

Robust and capable communications infrastructure is vital to the successful operation of a safe and reliable railway, and with the emergence of commercial mobile broadband and IP-based networks, the next generation of railway telecommunications will deliver far greater flexibility and reliability than is possible with legacy systems. The arrival of 4G LTE is an important development for the rail industry, not only because it brings the efficiency of proprietary telecommunications technology but also because it will allow the consolidation of multiple radio systems into one.

To give some idea of what is possible, the UK's Rail Authorities has indentified up to 55 operational applications which could be run on LTE, ranging from mobile ticketing, and catering to traffic management and driver advisory systems. Compared with GSM-R, LTE offers the prospect of lower maintenance costs and less downtime. Real-time information will be readily available on a variety of functions, giving the railway greater flexibility and improved responsiveness in the event of disruptions.

"Compared with GSM-R, LTE offers the prospect of lower maintenance costs and less downtime. Real-time information will be readily available on a variety of functions, giving the railway greater flexibility and improved responsiveness in the event of disruptions."

Continued from preceding page.

As we discover in this issue of TrackTalk, LTE will provide considerable benefits for passengers in terms of how they spend their time onboard (providing the quality of the coverage is excellent), with 4G broadband helping to enhance the attractiveness of rail transport and giving it an advantage over competing modes. It will also allow operators to significantly enhance passenger information provision, with real-time updates on services making train journeys easier to manage.

IP-based networks allow live streaming of video and enhanced safety functions such as monitoring platforms from the train. LTE would also allow level crossings to be monitored in real time from the cab of an

"Alcatel-Lucent combines extensive experience of delivering end-to-end solutions for rail customers with

IP-based networks allow live streaming of video and enhanced safety functions such as monitoring platforms from the train. LTE would also allow level crossings to be monitored in real time from the cab of an

"Alcatel-Lucent combines extensive experience of delivering end-to-end solutions for rail customers with

Secondly it is vital to consider frequency and spectrum usage, and this is a big issue because it is the key to accessing LTE. Railways are important strategic infrastructure and in some countries this argument is being leveraged to convince governments that spectrum needs to be allocated specifically for transport use. As Simon Bowyer of Mott MacDonald explains in this issue of TrackTalk, the need for spectrum to be dedicated solely to rail (as we saw with GSM-R) use is reduced, because LTE has all the necessary security features for safety-critical functions built into the application layer.

Continued from preceding page.

Nonetheless, industry bodies including the European Railway Agency (ERA) and International Union of Railways (UIC) are working to secure spectrum allocation for rail use, and setting spectrum aside at least for general transport use would be a step in the right direction.

The problem rail operators face is that spectrum is a high-value asset. Look at it from a government's point of view – if you sell it to a mobile operator, the revenue comes in immediately. Reserving spectrum for transport is effectively a long-term investment and it will take time to unlock all of the benefits. Nonetheless, improving transport telecommunications in this way will unlock significant benefits to the broader economy over time as passengers productivity is boosted and operations become more flexible and more efficient. Rail authorities therefore need to think carefully about how they put forward a business case to government for spectrum allocation.

There are also synergies between rail operators and the telecommunications companies that will be granted most of the available spectrum. There is a push for more private networks, as we saw with GSM-R, but it is likely to be the case that rail operators will not be able to rely on the availability of dedicated networks in the future for safety-critical functions.

Nevertheless, LTE offers low latency and a far greater interface efficiency than GSM-R or TETRA, so even with limited access to bandwidth, a huge range of applications can be consolidated into a single transmission network.

Continued from preceding page.

Rail LTE deployment will take divergent paths

We envisage metro and mainline migration to LTE moving at two different speeds. In the absence of a global standard for CBTC, metros have the flexibility to move to LTE relatively easily, and it is likely to be adopted relatively quickly, particularly on new lines. On main line railways, where international standards govern transmission networks for safety-critical systems, migration is likely to occur in two steps. Non-safety-critical applications that require broadband will probably be the first to switch over, and these applications will drive the migration for safety-critical applications, which in the meantime will remain on the industry standard GSM-R.

> "The railway must start to prepare the replacement of GSM-R and benefit now from advanced technology evolution."

As Alcatel states, *LTE offers "far greater efficiency than GSM-R or TETRA… even with limited… bandwidth… a huge range of applications … consolidated into a single… network."*

With *PTC-alone wireless*-- using narrow channels and radios in 220 MHz-range only– the US train industry is on the wrong track down slope to a broken trestle bridge, like in the old-time movie, *but this is real to tax payers and passengers.*

The federal government and tax payers should not allow it.

This currently planned PTC is somehwat like TETRA, noted above, but not nearly as mature and efficient: yet TETRA* is far inferior to LTE, and LTE-like tech and products available in 220-MHz range, if one uses sufficiently wide contiguous blocks. We discuss that below.

---

* TETRA uses TDMA in 25 kHz non-contiguous channels. US PTC as planned uses alleged types of TDMA in 12.5 kHz channels (as reported by, e.g., PTC 220 LLC, SEPTA, FRA on Amtrak (e.g. http://www.fra.dot.gov/Page/P0287).

- 2 -

Wideband Contiguous*

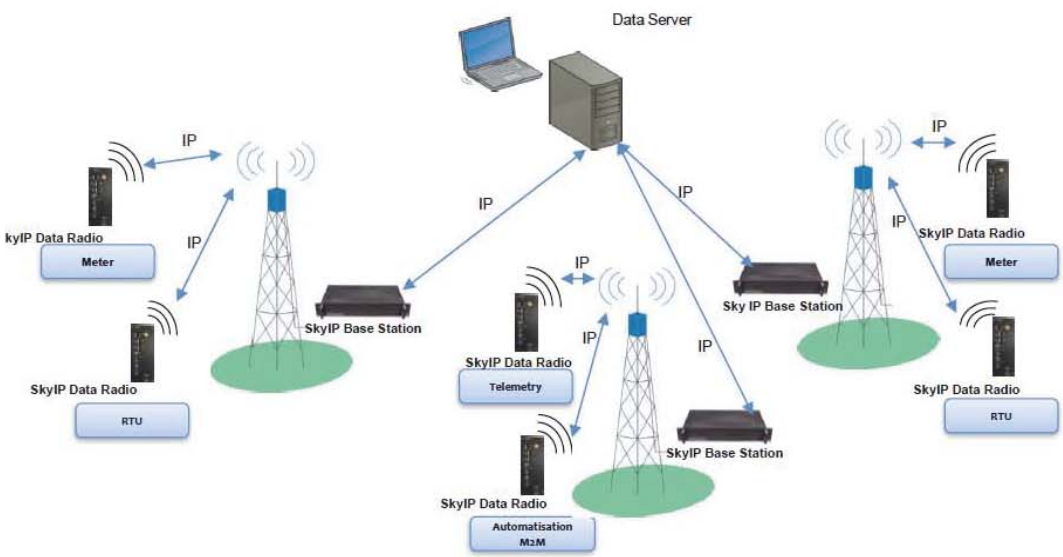
spectrum blocks

and benefits, including in 200 MHz

* We use “wideband” herein to mean substantially wider, by large multiples, of what is planned for PTC, and that can use LTE or LTE-like tech, in part indicated herein.

This is illustrative, not hereby a suggested technology or product. This is an example of an wider-band mission-critical VFH-range radio and system. *Note the comparison below between 12.5 kHz and 100 kHz bandwidth as implemented in this radio.* The SkySkweep company informed SkyTel (no relations between the companies) that they can radios in lower 200 MHz, upon commercial arrangements. Below is from: http://www.skysweep.com/index-2.html

Global High Speed IP Data Communication



The *SkySweep* IP over radio system devices:

SkyIPR-1 Telemetry Data Radio
- Frequency band 146-174 MHz or 400-512 MHz
- TX power max. 2 W
- 2 x RS232
- 1x RJ45 10/1000 ethernet
- DIN-RAIL-mounting
- Temperature range -20°C - +70°C

SkyIPR-2 Mobile Station
- Frequency band 146-174 MHz and 400-512 MHz
- TX power max. 20 W
- 2 x RS232
- 1x RJ45 10/1000 ethernet
- Temperature range -20°C - +70°C

SkyIPBS Base Station
- Frequency band 146-174 MHz and 400-512 MHz
- TX power max. 20 W
- 2 x RS232
- 1x RJ45 10/1000 ethernet
- 19 inch enclosure
- Temperature range -20°C - +70°C

Technical Data

- **Frequency range**

VHF Band	146 – 174 MHz
UHF Band	400 – 512 MHz

- **TX Power**

Telemetry Data Radio	max. 2 W
Terminal / Base Station	max. 20 W

- **Modes**

DMO (P2P point to point and P2M point to multipoint)
Trunking operation (IP Router und Bridge).

- **Channel bandwidth and max. data rates**

6.25 kHz	21 kbit/s
12.5 kHz	52.8 kbit/s
25 kHz	126.7 kbit/s
50 kHz	253.4 kbit/s
100 kHz	506.8 kbit/s
200 kHz	~1 Mbits

Note:
SkyDR IP data radio specifications (preliminary) might be subject to change due to product innovation and improvements without prior notice. This version: March 2013

FlexNet-One

Compact Vehicular Wide Band V/UHF Software Defined Radio

CONNECTIVITY AND MOBILITY

By integrating FlexNet-Waveform, the Thales FlexNet-One V/UHF SDR equipment offers high data rate transmission on the move, transverse communications and mobility management which strongly improve the connection between the users from headquarters to small action units.

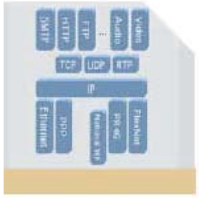
FlexNet-One brings to the users an increased level of services such as voice (digital or VoIP), data (short messages, formatted messages, file transfer), image and video transmission.

FLEXIBILITY

Based on an open architecture, compliant with Software Communications Architecture (SCA) international standard, and a powerful programmable hardware platform, FlexNet-One ensures enhanced functionality, expandability and waveform portability accommodating future technology or requirement upgrades with ease.

INTEROPERABILITY

The radio can be immediately reconfigured to provide interoperability with the PR4G standard and is open to host other standard waveforms (MIL-STD, Stanag) and national waveforms (Panther, SEM 93…) with national specificities.



SYSTEM INTEGRATION

By using and combining IP compliant protocols, FlexNet-One:

- Greatly improves the system integration in Local Area Networks or other tactical networks.
- Easily interfaces with standard applications such as Battlefield Management System, Information System or other IP standard applications.

With regard to vehicle integration, high performances co-site filters are provided to improve vehicular installations and communication system performances.

AFFORDABILITY

With its compact format, Flexnet-One is a tailored and affordable SDR solution for battlefield vehicle.

In addition with the new ad hoc networking waveform, FlexNet-One can be easily integrated in all kind of mobile vehicles. A form/fit compatibility of the worldwide operated Thales PR4G vehicular tactical radio greatly facilitates the installation.

FlexNet products are joint developments of Rockwell Collins and Thales, the worldwide leaders in SDR technology.

FEATURES

GENERAL CHARACTERISTICS

- Mobile ad hoc networking: self-organizing, self-healing, automatic routing upon mobile nodes
- Open architecture, full SCA compliant to ensure waveform portability and accommodate customized requirements and upgraded functionality
- Embedded or external high grade encryption including customer specific encryption
- Easy integration with IP networks and applications

PERFORMANCES

- **Frequency range:** 30 - 512 MHz
- **Bandwidth:** 25 kHz (V/UHF), 300 kHz, 1.25 MHz and 5 MHz (UHF)
- **Power output:** 50 W VHF and UHF
- **Data rate:** up to 64 kbps (VHF), up to 6 Mbps (UHF)
- **High performance VHF and UHF co-site filters**
- **Automatic power output** and duty cycle adaptation to optimize spectrum occupancy and power consumption
- **Internal or external GPS**

ENVIRONMENTAL CHARACTERISTICS

- Operating temperature: -40 °C to +70 °C
- Shock and vibration in accordance with MIL-STD-810E

INTERFACES

- Audio for combat net mode
- Ethernet 10/100 Mbps
- V24/V28 RS232 - PPP
- SNMP remote control

INSTALLATION

- Power supply: 28 V DC nominal
- Accessories: compatible with PR4G accessories (mount, antennas, handset, power supply, cables…)

This is illustrative, not hereby a suggested technology or product.

This is an example of an wider-band mission-critical VFH-range (and higher) radio and system.

This is from Rockwell Collins and Thales, designed for military use.

But the same tech can be used in non-military radios (excluding some features not needed outside military use, such as SCR): narrow up to wide band channels, multiple bands, and the noted advanced characteristics, etc.

Without use of wider contiguous channels, one cannot use radios that use such wider channels, and support higher data rates and more advanced applications (and greater total system capacity), etc. But with such wider channels, the system operator can always use more narrowband channels and modes (dividing the wider contiguous spectrum into any number of more narrow channels).

It is best to start with a contiguous block for current and future purposes.

This is illustrative, not hereby a suggested technology or product.

FullMAX: Broadband Wireless for Mission Critical Industries

OFDMA for max. coverage and reuse

Low latency network with QoS

Mobile Data @ 75 Mph

Configurable DL/UL capacity

EAP Authentication AES128 Encryption

FullMAX MS4000 Specifications

PHY

PHY	OFDMA with support for all Sub 1 GHz frequencies and narrow and wide channels
Adaptive Modulation & Coding (AMC)	QPSK ½ to 64QAM ¾
FFT Size (No. of Subcarriers)	128 FFT
Avg. Remote Data Rate	0.35 to 1.75 bps per hertz based on CINR and AMC
Sample Channels 200 kHz Channel 500 kHz Channel 1 MHz Channel	Remote Avg. Date Rate 70 kbps to 350 kbps 180 kbps to 870 kbps 380 kbps to 1.8 Mbps
TDD Frame Synchronization	GPS synchronization for multi-base station operation
Rx Sensitivity	-107 dBm
Permutations	Partial Use of Subchannels Uplink and Downlink

RF

Frequencies Supported	40 MHz to 958 MHz (5 kHz steps)
Channel Sizes	200 kHz to 5 MHz configurable
Duplex Method	TDD
Tx (effective transmit power)	Up to 10 Watts (40 dBm) Adaptive Power Control

Services

QoS types / Classes of Service	Best Efforts nrtPS rtPS ertPS UGS
Security	Authentication EAP Encryption AES 128

Mechanical / Electrical

User Interfaces	10/100 BaseT on RJ-45, RS232
Voltages	DC (9 to 36 VDC)
Size / Weight	11.02" x 7.87" x 2.80" (9 lbs) 30 cm x 20 cm x 7 cm (3.75 kg)
Temperature (F/C)	-22° F to140° F (-30°C to +60°C)
Humidity	95% humidity for 96 hours, 55% average humidity

Network Management

Management Protocol	SNMP, SSH Console Command Line Interface (CLI)
Software upgrades	Over the Air (OTA)
Remote management	FullMAX NMS SNMP

2452 Embarcadero Way, Palo Alto, CA 94303
www.fullspectrumnet.com
(888) 350-9994

Specifications and Performance subject to change

Full|Spectrum

Re: less guard channels needed for 1 contiguous block vs. many blocks.

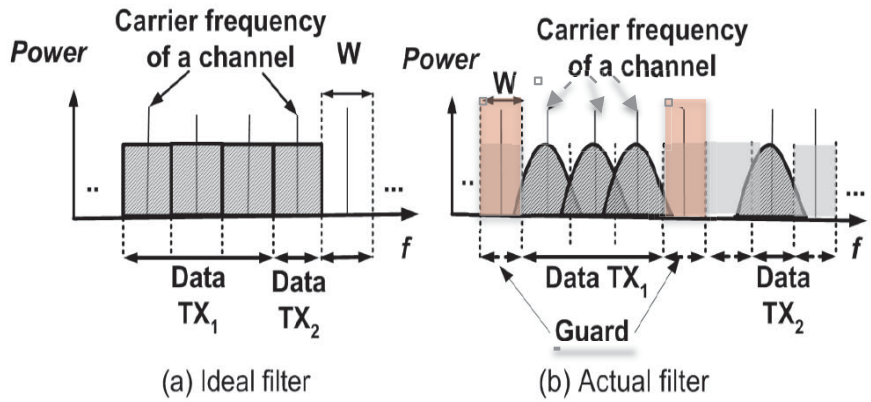


Figure 1: Ideal vs. actual transmission filters.

The diagrams on the left depict guard bands in "actual" (real world) radio-systems, on both ends of a number of frequencies used for data transmission (a channel).

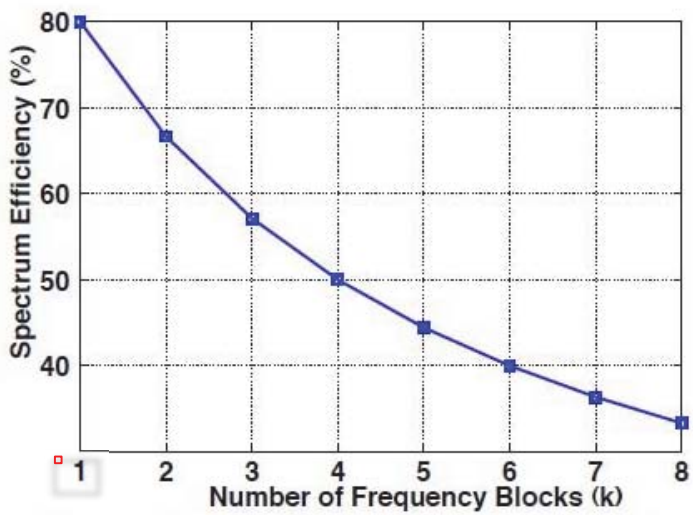


Figure 2: Number of required channels vs. number of blocks ($m = 8$).

" As a numerical example, assume that a given … transmission requires m = 8 data channels. Assume that the best 8 channels are non-contiguous and one guard channel on each side of a data channel is available. According to the greedy scheme, this … transmission requires 16 guard channels, which results in spectrum efficiency of 33%. Here, spectrum efficiency is defined as the ratio of the number of data channels and the total number of required data-plus-guard channels.

" On the other hand, if 8 adjacent data channels are available (i.e., one [contiguous] frequency block), the transmission will require only 2 guard channels. This results in spectrum efficiency of 80%. Figure 2 shows the total number of required channels as a function of k for m = 8.

Source of charts and quoted language: "Design and Evaluation of an Efficient Guard-band-aware Multi-channel Spectrum Sharing Mechanism,"
Copy at: www2.engr.arizona.edu/~krunz/TR/**guardband**_aware_Feb2011.pdf

Regarding VHF range guard bands, and further on contiguous blocks.

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Home > Products > Navigation Systems > Radio Navigation > VHF Transceivers

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VHF Transceivers

Applies to: Air Transportation & Regional

VHF Radio has long been the primary means of voice communications between aircraft operating in civilian airspace and Air Traffic Control. VHF Radios operate in the 118-137 MHz frequency band. Each VHF channel occupies 25 kHz so there are 760 channels that can be assigned to provide coverage in the various air space regions. The type of modulation used for voice communications is Double Side-Band Amplitude Modulation (DSB-AM) in which the voice audio from the microphone modulates the VHF carrier frequency. This type of analog modulation occupies about 7 kHz out of the 25 kHz channel assignment. The excess bandwidth in the channel is used as a guard-band to reduce the level of interference to adjacent channel assignments. Thus in today's architecture of the Air Traffic Control VHF network, sectors in the same general area may be assigned very closely spaced VHF channels.

Key Benefits

Platforms & Applications

Product Support

Aircraft Options and Upgrades
Asset Availability
BGA System Configurations
Download Catalogs
Product Brochures
Repair and Overhauls
Returns
Sales Bulletins
Spare Parts

VHF Radio has long been the primary means of voice communications between aircraft operating in civilian airspace and Air Traffic Control.

VHF Radios operate in the 118-137 MHz frequency band. Each VHF channel occupies 25 kHz so there are 760 channels that can be assigned to provide coverage in the various air space regions.

Here is an example of a mission-critical VHF* radio transceiver (transmit-receive radio) that occupies 25 kHz.

The data modulation uses “about 7 kHz”” leaving 18 kHz guard band spectrum: 9 kHz on each side.

While many factor affect suitable width of guard bands, SkyTel’s proposal allows effective guard bands on both ends of the proposed contiguous spectrum block: 10 kHz on one end, and that or greater on the other end. SkyTel will use these only in a way that “guards” the railroad’s use of the assigned block. The railroad will fully control adjacent-channel issues intra-block (whether it uses narrow or wider channels).

---

* VHF is 30-300 MHz, and includes 217-222 MHz.

2. Introduction to LTE and LTE-Advanced

Cellular technologies have evolved from the analog first-generation (1G) technologies to high-performance fourth-generation (4G) technologies in just about three decades. Figure 1 illustrates the evolutionary path of cellular technologies.

ARW as proposed herein is ~ here in combination of efficiencies and strengths.

PTC as planned is ~ here in terms of digital tech overall, ~ & here is terms of system capabilities

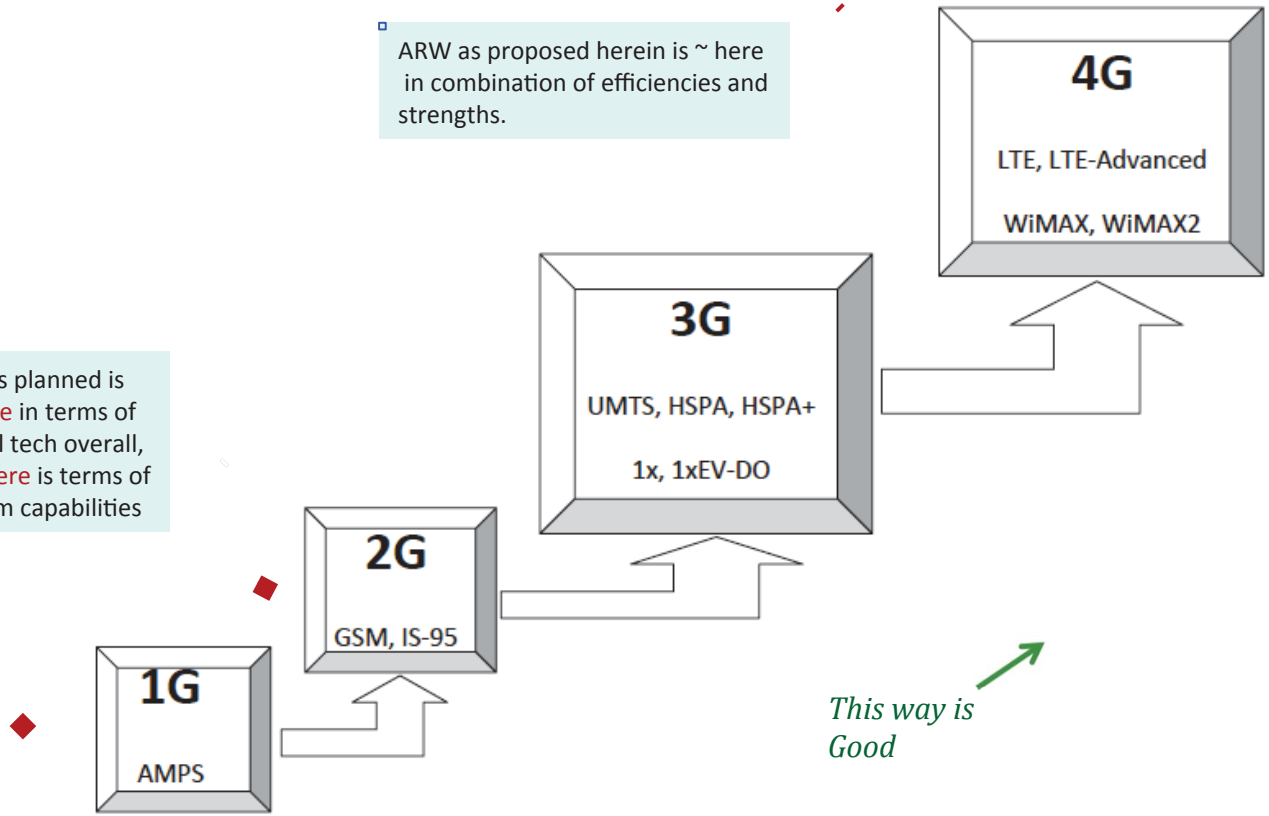


Figure 1. Evolution of Cellular Technologies

This is from a report commissioned by SkyTel.*

We add here the elements in color.

The advances from G to G are far larger than depicted by the box sizes by a factor of 10+.

This entire report is relevant to ARW. We include some excerpts on the following page.

* From Nishith D. Tripathi Ph. D., "LTE Deployments in the LMS band for ITS Radio Communications and Location, version 2," August 2012. Copy at: http://www.docshut.com/kihunt/lte-for-m-lms-900-mhz-for-intelligent-transportation-systems-n-d-tripathi-aug-2012.html

7. LTE and LTE-Advanced for Vehicles and Trains

From the Tripathi report cited on preceding page.

While generic UEs and eNodeBs would work for the LMS band, some of the ITS applications such as the Internet access for train passengers and the access to IMS applications along the highways could benefit from a higher degree of customization. Example areas of such customization include increased power levels of the UE and the use of more physical antennas.

A typical Power Class 3 UE has the maximum transmit power of 200 mW or 23 dBm. Depending upon the type of the device, it is possible to increase the maximum transmit power by using a power amplifier with higher power rating. Such UE can be used in train compartments as a MiFi[8] to serve train passengers using WiFi laptops and smart phones. A higher maximum transmit power can be exploited to increase the cell size or improve cell-edge throughput performance for a given cell size.

Release 8 LTE supports up to four antennas at the eNodeB and the UE, and LTE-Advanced supports up to eight antennas. While a typical handset has limited space to be able to house more than two LTE antennas, the UEs customized for trains and vehicular applications could be made larger and hence could house more than two antennas, perhaps four or even eight. The coverage along the railway tracks and highways would typically involve two cells (or sectors) per eNodeB instead of three cells (or sectors) per eNodeB in a typical cellular scenario. Hence, it will be relatively easier to use more antennas per cell at the eNodeB. The feasibility of more antennas at both the UE and the eNodeB in the trains and in the vehicular environment means that higher peak and average throughput can be achieved via SU-MIMO and beamforming. Furthermore, more battery power is available on the trains and in the vehicles compared to traditional cellular handsets to enable use of more complex and intensive antenna techniques (especially for the uplink transmissions) while ensuring a long battery life.

A preliminary analysis carried out for SkyTel indicates that the LTE deployment in the LMS band for a train corridor (e.g., North East Corridor) is feasible and its expected coverage is comparable to the use of LTE in the traditional cellular networks. The analysis used -105 dBm noise from the Part 15 users for the LTE uplink link budget calculations. The measured Part 15 interference in metro areas ranged from -105 dBm to -80 dBm in Shared Spectrum reports. Since the Part 15 devices and systems are less likely to be close to railway tracks, a noise value close to the minimum level is appropriate. Other link parameters include the eNodeB receiver noise figure of 4 dB, the eNodeB receive antenna gain of 21 dB, and the resource allocation for 2 Physical Resource Blocks to achieve the average cell-edge data rate of about 60 kbps, 40% uplink (and 60% downlink) for the TD-LTE configuration, signal to noise ratio (SNR) of 2.4 dB for the reliable detection of the packets for a UE at the cell-edge (corresponding to QPSK modulation and 1/3 coding), interference margin of 1 dB, shadow fading margin of 5.4 dB for 75% cell-edge reliability. The uplink link budget was found to be 139 dB. Assuming the center carrier frequency of 907 MHz for a 5 MHz TD-LTE system, **the cell radius is 3.6 miles for a suburban environment and 12.1 miles for an open space (rural) environment** based on the widely used Hata propagation path loss model. When the cell radius is 3.6 miles, two eNodeBs are spaced apart by (2*3.6 = 7.2 miles). Since the cell radius greater than 3 km is projected to be very valuable, the LMS LTE is thus quite promising and even has a good margin to work with.

Continued from above page.

A preliminary analysis carried out for SkyTel indicates that even a narrow band version of LTE using just 1.4 MHz wide channel in the 217-235 MHz range could be quite useful. In particular, since the propagation path loss is much less at lower frequencies than at higher frequencies, a large cell size is feasible for LTE. The deployment could be quite inexpensive in the 217-235 MHz range. This frequency range could be used to supplement the regular LMS LTE coverage or to add extra capacity. Even carrier aggregation could be exploited across the LMS band and this 200 MHz band.

Examples of the ITS data that can be transmitted using eMBMS include weather, road conditions, changes in metro-transit and inter-city public transport schedules, location-based advertising and availability information (e.g., gas and alternative-fuel stations, hotels, food services, medical facilities, road-side attractions, and special events). In addition to efficiently transmitting such ITS data, eMBMS can also be exploited to transmit Network Real-Time Kinematic (NRTK)[5] positioning data to achieve millimeter-level (e.g., 10 to 15 mm) location accuracy[6]. As reported in [NRTK_Ireland], mobile infrastructures of 2G and 3G cellular technologies (and broadcast radio) are being used to support the NRTK positioning systems in Ireland. LTE can thus easily be utilized to facilitate implementation of the NRTK method.

Continued from above page.

- - - - -

"eMBMS" is a one-way broadcast service in LTE.

SkyTel plans to use this (among other forms of LTE), but also to use DRM in 200 and 40 MHz ranges, noted below.

---

[5] In the basic RTK positioning method [NRTK_Langley], a receiver at a reference site makes measurements that are transmitted to one or more rover receivers (e.g., mobile devices). The rover receivers combine their own measurements with the measurements received from the reference sites and accurately determine their coordinates. However, atmospheric and satellite-position errors decorrelate with increasing distance between reference sites and rover receivers. Hence, the location accuracy decreases with distance, limiting the effective distance between reference sites and rover receivers. The Network RTK method overcomes such distance limitation of the basic RTK method. In the NRTK method, data from a number of reference sites are used to determine the measurement errors across the network and corrections are provided to the rover receivers. The accuracy of the location estimate at the rover receiver is thus enhanced [NRTK_Langley].

[6] Some researchers are working on methods such as the use of mesh net for vehicle-to-vehicle communications to achieve sub-meter accuracy with high reliability [MeshNet]. The 5.9 GHz band identified for the DSRC as mentioned in Section 3 can be used for such vehicle-to-vehicle communications.

- 3 –

High Accuracy Location (HALO)

with one-way Broadcast data

for “RCAS” - Railroad Collision Avoidance Systems,

(i) makes PTC *redundant*, and

(ii) is, by an order or magnitude or more,

more cost effective to deploy and maintain,

and is needed anyway for ARW.

(Re: “RCAS” = Railroad Collision Avoidance System)

This describes an *additional* form of wireless for railroad safety. *SkyTel entities' spectrum is very suitable for this, as well.*

From: See next page for paper title and authors. Copy at this link:
http://www.researchgate.net/publication/224116357_Multi-broadcast_communication_system_for_high_dynamic_vehicular_ad-hoc_networks/file/32bfe51248be214110.pd

***Abstract*—The implementation of Safety of Life (SoL) services in transportation systems, e.g. for applications like collision avoidance of vehicles, requires reliable and instantaneous information exchange. In this paper we present the design of an infrastructure-less ad-hoc inter-vehicle communication system that fulfills these requirements with respect to the boundary conditions in the railway environment, where a limited communication range and relatively high speeds of nodes cause the network to be highly dynamic. Moreover, in areas with high user densities the common media access is a challenge due to limited bandwidth and interference from other wireless systems.**

I. Introduction

STATISTICS of the International Union of Railways (UIC) show, that there are three significant train accidents in Europe every day [1], despite of millions of Euros which have been invested in trackside and in-train safety equipment. Even with Automatic Train Control (ATC) systems like the future European Train Control System (ETCS) a significant amount of accidents cannot be prevented, because they occur between trains and other kinds of obstacles like construction vehicles, construction workers or pedestrians and vehicles on level crossings.

In order to increase safety in railway traffic, a vehicle integrated collision avoidance system similar to the existing ones in maritime or air transportation [2], is proposed. Conceptual this provides a safety overlay level that would take effect in situations that caused most accidents in recent years The advantages are higher safety as well as more efficient use of railways on an international level at low cost and without changes to existing infrastructure and independent of the various railway control mechanisms.

While suitable solutions for the inter-vehicle communication link were developed for the maritime AIS (Automatic Identification System) and the aeronautical TCAS/ADS-B [3] (Traffic Alert and Collision Avoidance System / Automatic Dependent Surveillance - Broadcast), the railway specific boundary conditions necessitate a new design for RCAS and other applications where there are

- (punctually) very high user densities,
- the network dynamic is high due to a relatively short communication range and high user speeds, and
- bandwidth limitation and/or robustness against interfering systems

is mandatory.

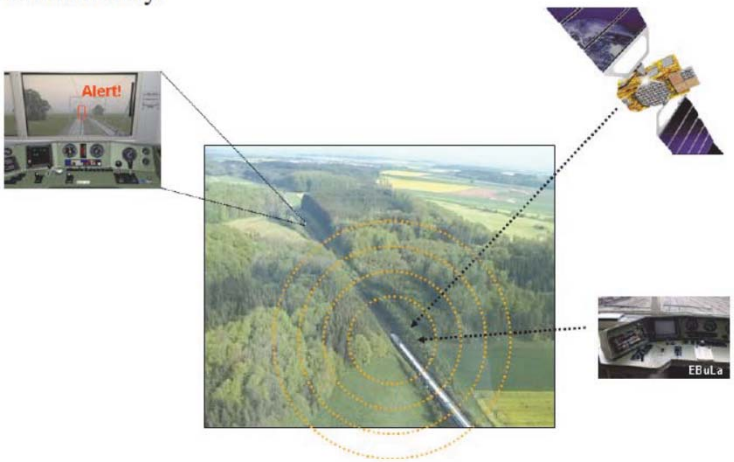


Fig. 1. Principle of collision avoidance based on the broadcast of traffic relevant information among vehicles, illustrated for the railway case.

(Re: "RCAS" = Railroad Collision Avoidance System)

Continued from previous page.* *(Re: "RCAS" = Railroad Collision Avoidance System)*

III. RCAS Architecture

On board of each rail vehicle an intelligent RCAS unit is foreseen, comprising sensors, a transceiver and a processor unit as shown in Fig. 2. The sensors are used for accurate track resolving localization. A combination of GNSS (Global Navigation Satellite System) receiver, odometer and eddy current sensor can be used [5]. The last one not only improves the accuracy along the track by detecting rail clamps, but also allows identification of switches and the switch stand by unique signatures. Aided by an electronic map this guarantees precise rail selective PVT information even in tunnels, under roofs of train stations and in shunting yards with many parallel tracks.

Together with train specific parameters like its dynamic behavior, the PVT data is broadcasted via the RCAS communication unit. As well each unit receives messages from nearby trains and analyses this data together with its own status in the RCAS algorithm to identify collision threats and give warnings or even braking commands to the

TABLE II

COMPARISON OF NETWORK DYNAMIC AND NODE DENSITY FOR COLLISION AVOIDANCE APPLICATION IN DIFFERENT TRANSPORTATION SYSTEMS

Transport system	Min. comm. range	Maximum velocity	Topological network dynamics	Max. number of nodes within range
Ships - AIS SOTDMA	40 km	60 km/h	1,5 h^{-1}	75
Airplanes - TCAS ALOHA	56 km	1000 km/h	16 h^{-1}	30
Trains - RCAS COMB	5 km	200 km/h	40 h^{-1}	250

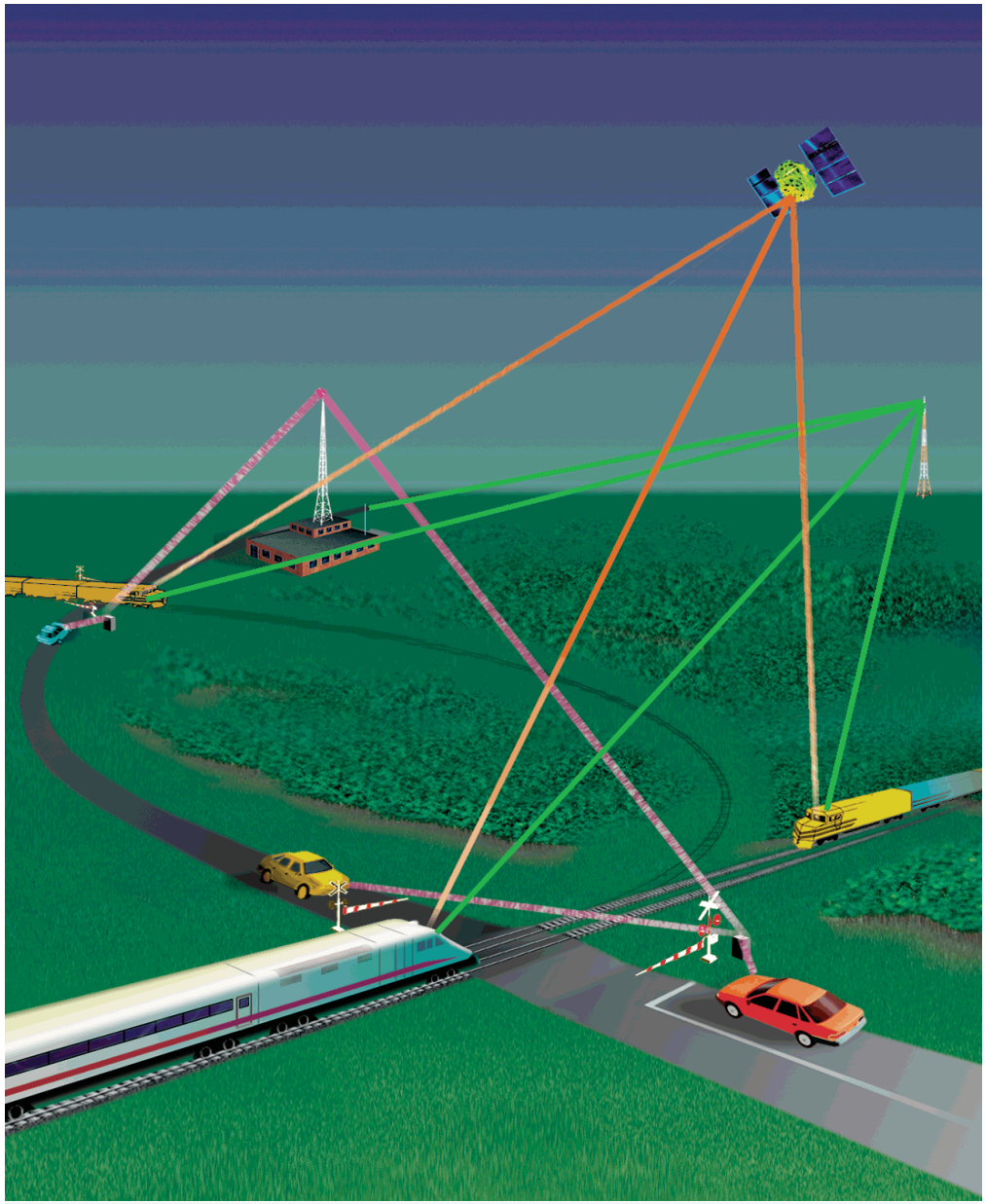
Because of the limited channel resources and the high node density together with the high network dynamic it was necessary to develop a new class of MAC protocols called COMB that we published in [17]. This Cell based Orientation aware MANET Broadcast MAC layer utilizes the information of the nodes about their location, direction, speed, and precise timing. The world map is divided into virtual hexagonal cells as illustrated in Fig. 8. Neighboring cells are distinguished by different spreading codes and

This and previous pages are excepts from:

Multi-Broadcast Communication System for High Dynamic Vehicular Ad-hoc Networks

Andreas Lehner, Cristina Rico-García, Eugen Wige, and Thomas Strang,
Institute for Communications and Navigation, German Aerospace Center DLR

SkyTel entities' nationwide plan has, as a core application – high accuracy position, timing and navigation (HA PNT). We have an ideal combination of 3-bands of spectrum for this, using broadcast, mobile peer-peer, and two-way modes, and delivery of constant Network RTK GNSS correction data for sub-decimeter accuracy combined with onboard INS, etc. HA PTN will improve even further the type of railroad (trains) RCAS described above. ("RCAS" = Railroad Collision Avoidance System)



Depiction credit: Steve Ditmeyer, SCORT/TRB, Rail Capacity Workshop, September 22, 2010

Continued from previous page.*

SkyTel entities' nationwide plan has, as a core application – high accuracy position, timing and navigation (HA PNT). We have an ideal combination of 3-bands of spectrum for this, using broadcast, mobile peer-peer, and two-way modes, and delivery of constant Network RTK GNSS correction data for sub-decimeter accuracy combined with onboard INS, etc.

This is used to depict GPS-GNSS signals (orange) (but assume there are many GNSS satellites visible and used), Network RTK correction signals via long-range BROADCAST (green), and two-way communications (purple).

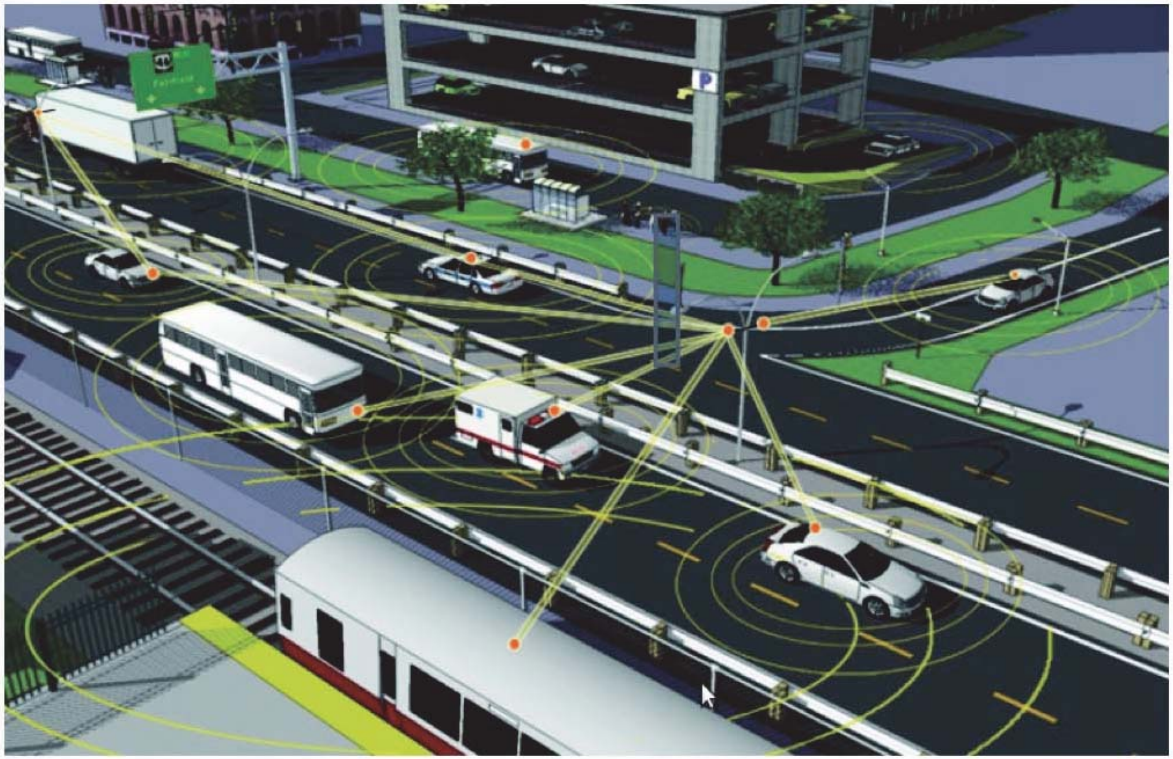
Broadcast N-RTK will provide DECIMETER accuracy (see below) to moving trains, trackside vehicles and workers, passengers, etc.

(This NA PNT component of Advanced Railroad Wireless is continued below.)

Network RTK for Intelligent Vehicles

February 1, 2013 - By GPS World staff

http://gpsworld.com/network-rtk-for-intelligent-vehicles/



Accurate, Reliable, Available, Continuous Positioning for Cooperative Driving

-

(Broadcast) MAX:

- –Works with radio and other one-way communication media.
- –Uses a fixed cell that is defined by the network operator.
- –The rover user must ensure that they connect to a suitable correction service.
- –Available in the London Olympics Site.

http://cesi.cumt.edu.cn/Upload/PicFiles/2013.3.15_11.6.18_9534.pdf

Network RTK for Intelligent Vehicles

February 1, 2013 - By GPS World staff

Continued

Real-time vehicle localization is one of three key enabling technologies for the concepts of vehicle-to-vehicle and vehicle-to-infrastructure (V2V and V2I, collectively termed V2X, see opening graphic), a classification of intelligent transport systems (ITS). The further enabling technologies are ad-hoc dynamic networking of agents, and accurate dynamic local traffic maps. Jointly, these require that positioning be accurate, reliable, available, and continuous.

A natural evolution in road transport, V2X promises to deliver the next major safety breakthrough. The concept moves away from vehicles making individual decisions about road safety, as in advanced driver assistance systems, and towards a cooperative driving approach that shifts the emphasis from collision protection to collision prevention. The U.S. National Highway Traffic Safety Administration estimates that V2X technology can avoid or minimize up to 80 percent of collisions of unimpaired drivers, and that even a small number of deployed vehicles will provide tangible safety benefits.

Network RTK GNSS positioning, like V2X applications, requires a communication system; and by its nature V2X has a positioning solution requirement. Thus it is envisioned that network RTK will play an essential role in the implementation of V2X systems.

* * * *

Digital Audio Broadcasting (DAB) is capable of being used as a future communication method for network RTK positioning. Compared to traditional VHF and UHF radio communication [two-way land mobile radio], it uses the frequency more efficiently and is more robust to degradation

SmartNet NRTK: Tests Results

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

CENTIMETER ACCURACY

Static Tests Accuracy and Precision

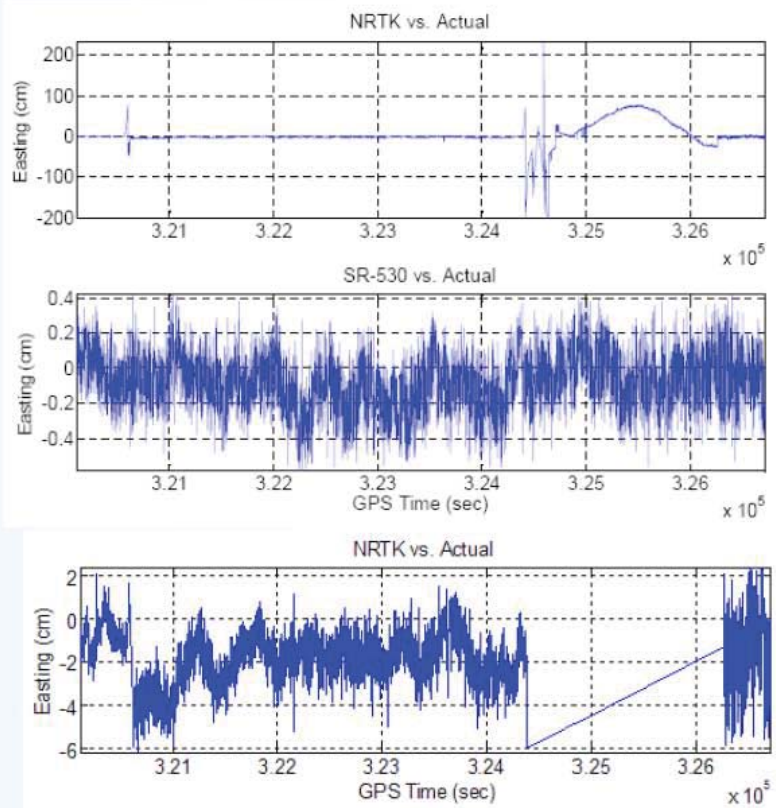
All Epochs

Test	Accuracy (cm)			2DRMSE (cm)	3DRMSE (cm)	Precision (+/- SD cm)		
	ΔE (cm)	ΔN (cm)	ΔH (cm)			E	N	H
TS1	-1.03	-3.27	4.36	3.43	5.55	0.13	0.50	0.62
TS2	-0.98	-3.72	1.68	3.85	4.20	0.05	0.11	0.33
TS3	-0.67	-3.69	5.03	3.74	6.27	3.15	5.20	9.57
TS4.1	5.11	-16.69	24.75	17.46	30.28	24.91	30.50	42.09
TS4.2	-1.59	-3.14	3.47	3.52	4.94	3.38	3.05	6.19
TS5.1	-0.98	-3.20	4.06	3.34	5.26	1.79	3.37	5.40
TS5.2	-1.60	-2.97	4.34	3.37	5.49	1.23	2.41	3.89

NRTK Epochs

Test	Accuracy (cm)			2DRMSE (cm)	3DRMSE (cm)	Precision (+/- SDcm)		
	ΔE (cm)	ΔN (cm)	ΔH (cm)			E	N	H
TS1	-1.03	-3.27	4.36	3.43	5.55	0.13	0.50	0.62
TS2	-0.98	-3.72	1.68	3.85	4.20	0.05	0.11	0.33
TS3	-1.17	-2.97	3.61	3.19	4.82	1.24	2.04	3.72
TS4.1	-1.82	-2.02	4.19	2.72	5.00	1.23	1.23	2.38
TS4.2	-1.60	-3.07	3.40	3.46	4.86	2.80	2.66	5.40
TS5.1	-1.12	-2.71	3.56	2.94	4.62	1.13	1.86	3.91
TS5.2	-1.56	-2.91	4.34	3.31	5.46	1.14	2.01	3.59

TS4.1



http://cesi.cumt.edu.cn/Upload/PicFiles/2013.3.15_11.6.18_9534.pdf

	Easting	Northing	Height	2D
Lap 1				
S.D.	0.004	0.006	0.008	0.007
MAX	0.055	0.064	0.067	0.084
MEAN	0.004	-0.002	0.040	0.005
99%	0.008	0.011	0.020	0.014
95%	0.005	0.009	0.014	0.011
90%	0.004	0.007	0.011	0.008
50%	0.000	0.000	0.001	0.000
Lap 2				
S.D.	0.014	0.013	0.008	0.019
MAX	0.198	0.185	0.067	0.271
MEAN	0.007	-0.006	0.040	0.009
99%	0.010	0.013	0.020	0.016
95%	0.006	0.009	0.014	0.011
90%	0.005	0.007	0.011	0.009
50%	0.000	0.001	0.001	0.001
Lap 3				
S.D.	0.010	0.010	0.010	0.014
MAX	0.197	0.201	0.042	0.281
MEAN	0.009	-0.018	0.007	0.021
99%	0.009	0.012	0.022	0.015
95%	0.007	0.008	0.017	0.011
90%	0.005	0.007	0.014	0.009
50%	0.000	0.000	-0.001	0.001

Table 1. Comparison of the tightly coupled (GPS+IMU) solution with the N-RTK solution.

The worst absolute accuracy is shown during lap 3, although even in this case, with a mean of 21 millimeters and 99 percent of the observations lying within 15 millimeters, this solution still delivers a solution within 36 millimeters of the ground truth. 50 percent of the network RTK observations are within 1 millimeter of the mean difference between the two solutions, showing remarkable consistency and precision.

http://cesi.cumt.edu.cn/Upload/PicFiles/2013.3.15_11.6.18_9534.pdf

- 4 -

Advanced Railroad Wireless

(Read above slides first to better understand the below.)

(Also, we describe above, and in the first 3 pages below of *text* slides below, components for our proposed *US ARW* that will expand and improve what is outlined in *graphic* slides later below, which draws mostly from leaders in LTE for Railroads outside of the US.)

Advanced Railroad Wireless (ARW) Initial Study (SkyTel)

The study involves use for NEC passenger railroads' operations, including MTA's operations, of wide radio frequency spectrum blocks in the following radio services and frequency bands:

(a) the "AMTS" Service in 217-220 MHz (in greater amounts than in),

(b) the "M-LMS" Service in the lower 900 MHz (in multi-MHz bandwidth),

(c) the "DSRC" Service in the 5.9 GHz range (in 10 MHz or more bandwidth), and

(d) the "Paging" service licenses in the 35 and 43 MHz VHF "Low Band" range.

SkyTel entities, SkyTel, holds FCC licenses in all these services and bands except DSRC: these holdings are described and mapped in slides below.

DSRC is the "sister" band to M-LMS. These are the two compose the "Intelligent Transportation System Radio Service" established by the FCC under Part 90 subpart M of its rules. DSRC at 5.9 GHz is for short-range and M-LMS in lower 900 MHz is for long-range wireless coverage. AMTS in lower 200 MHz is for still longer-range and more-robust coverage, and the 30-40 MHz Low Band spectrum is for super -long-range and –robust coverage. In mission-critical wireless over wide areas and corridors, redundancy in coverage and diversity in bands is especially important.

The ARW Study will involve use, without limitation, of the following (some of these further discussed below an in the Appendix-1 Slides:

(a) LTE and LTE-like technology, products and systems in these spectrum bands.

(b) Integration with commercial broadband wireless systems as used by these railroads ("RRs") passengers and staff, with a high level of "firewall" and other controls.

One of the goals is to achieve no-gap highly-secure high-speed wireless communications for both train operations, and for passengers—with no gaps, including for passengers by covering the coverage gap in locations and times of the commercial wireless systems and WiFi systems that provide varying levels of service along the railroad corridors and stations. The lower range spectrum described above (900 MHz and below), placed into service at fixed based stations of the railroads, can achieve this.

(Cont'd) Advanced Railroad Wireless (ARW) Initial Study (SkyTel)

(c) Two-way wireless communications, as well as one-way broadcast wireless such as by use of "Digital Radio Mondiale" ("DRM") employing some of the 35-43 MHz spectrum, and some of the AMTS lower- 200 MHz spectrum.

(d) High-accuracy Positioning, Timing, and Navigation ("PNT") using certain currently available technologies and systems including "Network RTK." This is critical for many applications, both for railroad operations, and for passengers, including passengers with disabilities.

(e) Coverage above ground, and through underground railroad facilities and tracks (subways), with no gaps.

SkyTel projects, for railroad operations by themselves, over order of magnitude increase in per-station, per-link, and overall system capacity-- at only small additional capital and operational expenditures-- as compared to implementation of PTC-only wireless systems on lower 200 MHz. There would be a multiple of wireless capacity in addition, also at only modest additional costs, for service to passengers via the function indicated above.

The goals, radio spectrum, technologies, equipment, systems, and means to implement the advanced railroad wireless systems outlined herein are all currently availably. Like systems are already deployed and others are being planned in various major metropolitan areas of the World, but with the spectrum indicated above, the US NEC passenger railroads can have a superior system. The Appendix-1 Slides demonstrate some of these, and all of these are easy to verify. It is important to look outside of much of the current thinking and trajectories of parties not aware of these, or who would not benefit from implementation of the indicated goals of this NEC Study.

The implementation SkyTel has in mind on the spectrum bands and bandwidths noted above would not only increase by a large multiple the wireless data capacity for train operations, and thus increase safety, security, efficiency, etc., but also provide high-speed wireless access into the trains for passengers. This would be easily combined with on-board commercial and WiFi wireless to the extent those are available in many locations and train-movement conditions.

Use of dedicated mission-critical-grade radio spectrum and systems described above will provide constant and more reliable wireless access for passengers than by use of only commercial and WiFi wireless. Gaps in coverage and reliability is a major detraction in wireless access, and the just noted improved high-speed wireless assess to passengers should increase ridership and revenues, etc.

(Cont'd) Advanced Railroad Wireless (ARW) Initial Study (SkyTel)

The train operations would always have priority use of the multi-band wireless systems, and in emergencies would preempt capacity used for passengers in non-emergency situations. This would be another benefit.

As general references, the following are papers SkyTel commissioned relevant to this NEC Study outline:

A paper by Dr. Nishith Tripathi on the use of LTE in M-LMS in 900 MHz (where we have 5+ MHz bandwidth available), and in AMTS in 200 MHz:
http://www.scribd.com/doc/104580013/LTE-for-M-LMS-900-MHz-for-Intelligent-Transportation-Systems-N-D-Tripathi-Aug-2012

A paper on the wireless for railroads by Ron Lindsey:
http://www.scribd.com/doc/53478557/Wireless-for-Railroads-By-Ron-Lindsey-April-2011

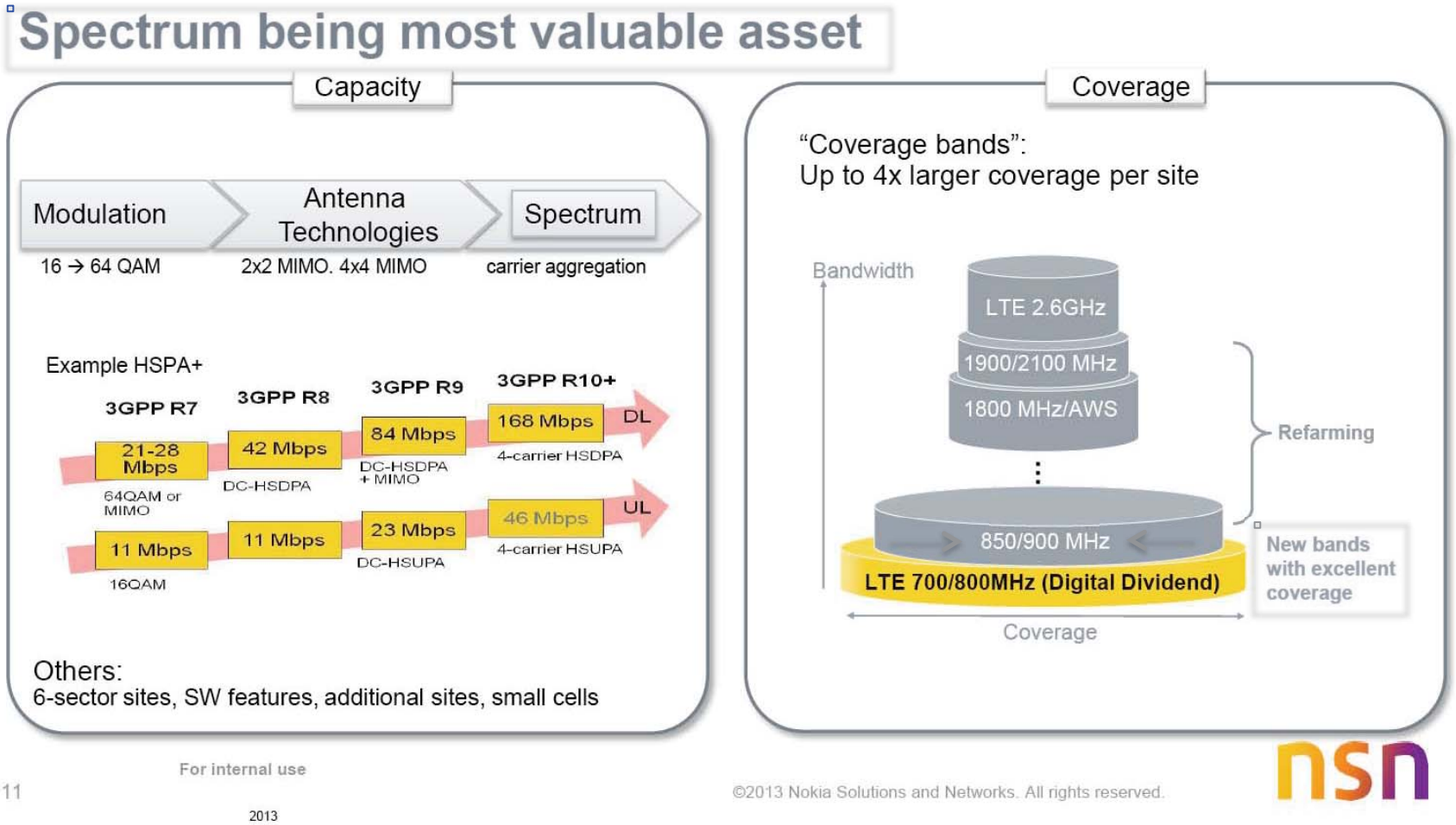
A paper by the University of California, Berkeley, Institute of Transportation Studies on ubiquitous, nationwide high-accuracy location (position, navigation and timing)
http://www.eecs.berkeley.edu/~kannanr/assets/project_loc/CHALOCBA.pdf

Slides below provide further information on this Study rationale and justification, potential technologies, etc. These are by world leading companies and authorities in advanced wireless, including advanced wireless for railroads.

SkyTel licenses. At the end, in Part 3, below are slides describing and mapping the AMTS 217-220 MHz, M-LMS 900 MHz, and 35/43 MHz licenses of ENL and the other SkyTel entities.

/ / /

From "LTE industry snapshot," by Nils Kleemann, Head MBB Solutions, APAC, Nokia Solutions and Networks. 12/9/2013



From: http://www.mastel.or.id/files/LTE%20Application%20in%20Real%20World.pdf

Continued, same publication

How important is to reach *population coverage* quickly?

… and where.

> "Coverage is just as important as speed…
>
> … when users fall out of LTE coverage zones and are switched back to 3G speeds, it is not a nice experience"
>
> *European operator*

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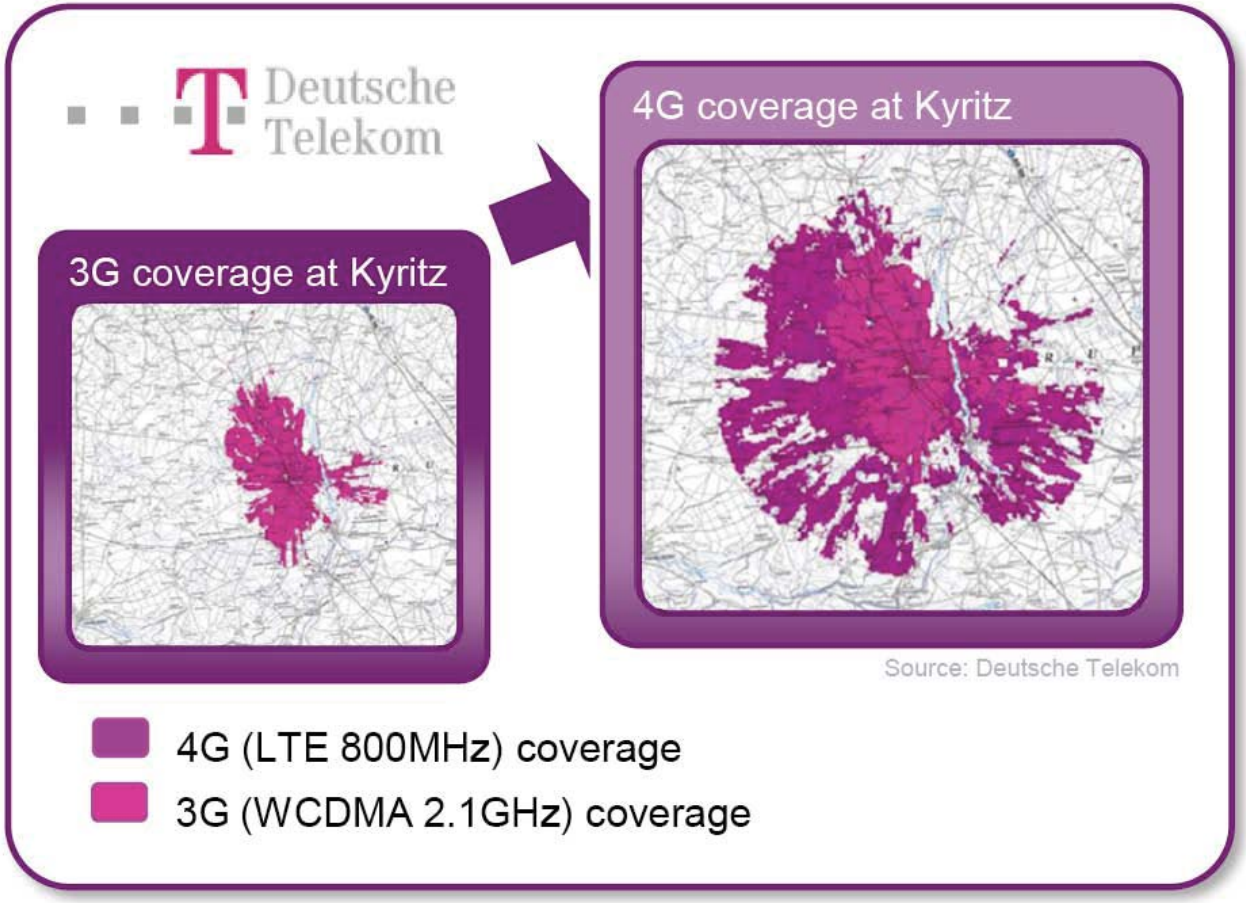
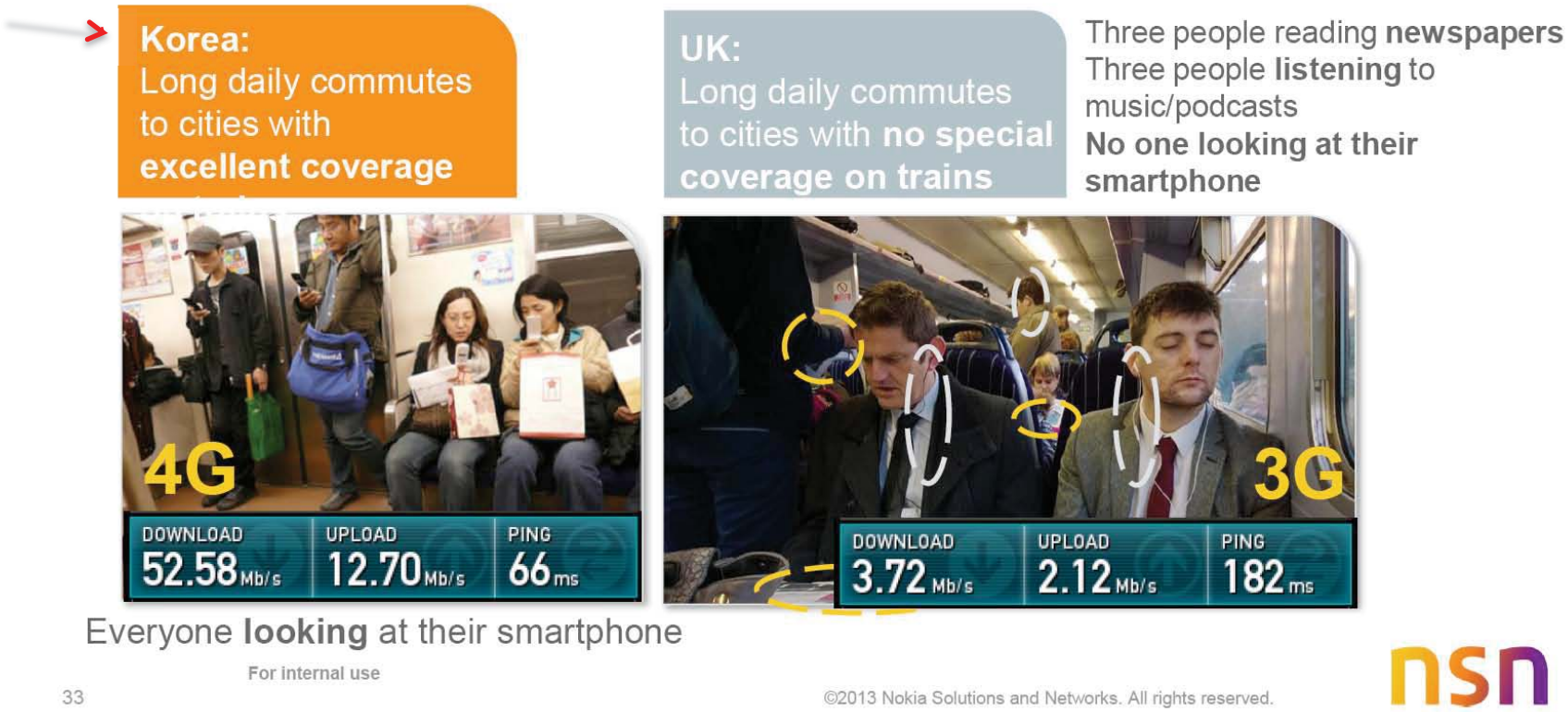
From: http://www.mastel.or.id/files/LTE%20Application%20in%20Real%20World.pdf

Continued, same publication



From: http://www.mastel.or.id/files/LTE%20Application%20in%20Real%20World.pdf

Continued, same publication



From: http://www.mastel.or.id/files/LTE%20Application%20in%20Real%20World.pdf

Continued, same publication

LTE's influence on Wifi

EE UK, August 2013:

Since using 4G, 43% use fewer or no public Wi-Fi hotspots (up from 37% in April)

LTE1800 (20 MHz)	WCDMA2100 (5 MHz)	WiFi

Seoul subway speedtest, October 2013
All three networks provided by same operator

South Korea:

"Why would anyone want to use public Wi-Fi when LTE is so much better?"

Might not be everywhere

Influencing factors:

- Cost
- Convenience
- Quality
- Public vs private Wi-Fi

For internal use

34

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From: http://www.mastel.or.id/files/LTE%20Application%20in%20Real%20World.pdf

From document identified below

California High-Speed Train Project

TECHNICAL MEMORANDUM

Automatic Train Control and Radio Systems: Requirements, Solutions and Radio Frequency Spectrum Challenges TM 300.04

05 May 11
Date

5.3.5 LTE for voice and data

LTE is a 4G wireless technology considered next in line in the GSM evolution path after Universal Mobile Telecommunications System (UMTS) / High Speed Packet Access (HSPA) 3G technologies. LTE is currently being developed by the 3GPP, aimed at evolving 3GPP's third generation system towards an all-IP network optimized for high speed data transmission.

Rather than further developing current HSPA and modulation schemes based on the Wideband Code Domain Multiple Access (W-CDMA) used in third generation UMTS cellular systems today, LTE uses Orthogonal Frequency Division Multiplexing (OFDM) as its radio access technology, together with advanced antenna technologies.

UIC's investigation into LTE to for ERTMS is planned to start in 2020; however, LTE will most likely be a commercially dominant technology before then. Furthermore, public safety agencies including Association of Public-Safety Communications Officials (APCO), the National Emergency Number Association (NENA) and the National Public-Safety Telecommunications Council (NPSTC) have endorsed LTE as the preferred technology for a proposed national broadband network for first responders in the 700 MHz spectrum band. Even though LTE has not been completely defined as of this writing, for the above reasons, LTE is a technology to investigate to support the CHSTP radio requirements.

The LTE specification provides downlink peak rates of at least 100 Mbps, an uplink of at least 50 Mbps and Radio Access Network round-trip times of less than 10 ms.

Huawei, the network infrastructure provider, has demonstrated an LTE system on board a train that has a top speed of 268 mph and averages 156 mph that covers 19.25 miles in only 7 minutes and 20 seconds. When the train first leaves the station it supports an LTE network speed of 46 Mbps, and when the train is at top speed the data speed drops to 36 Mbps.

From: http://www.hsr.ca.gov/docs/programs/eir_memos/Proj_Guidelines_TM300_04R0.pdf

From: Steffen Amundsen, “Future Rail Communication - Implementation Scenarios for LTE, June 2013

CHAPTER 4. INCENTIVES FOR A FUTURE LTE NETWORK

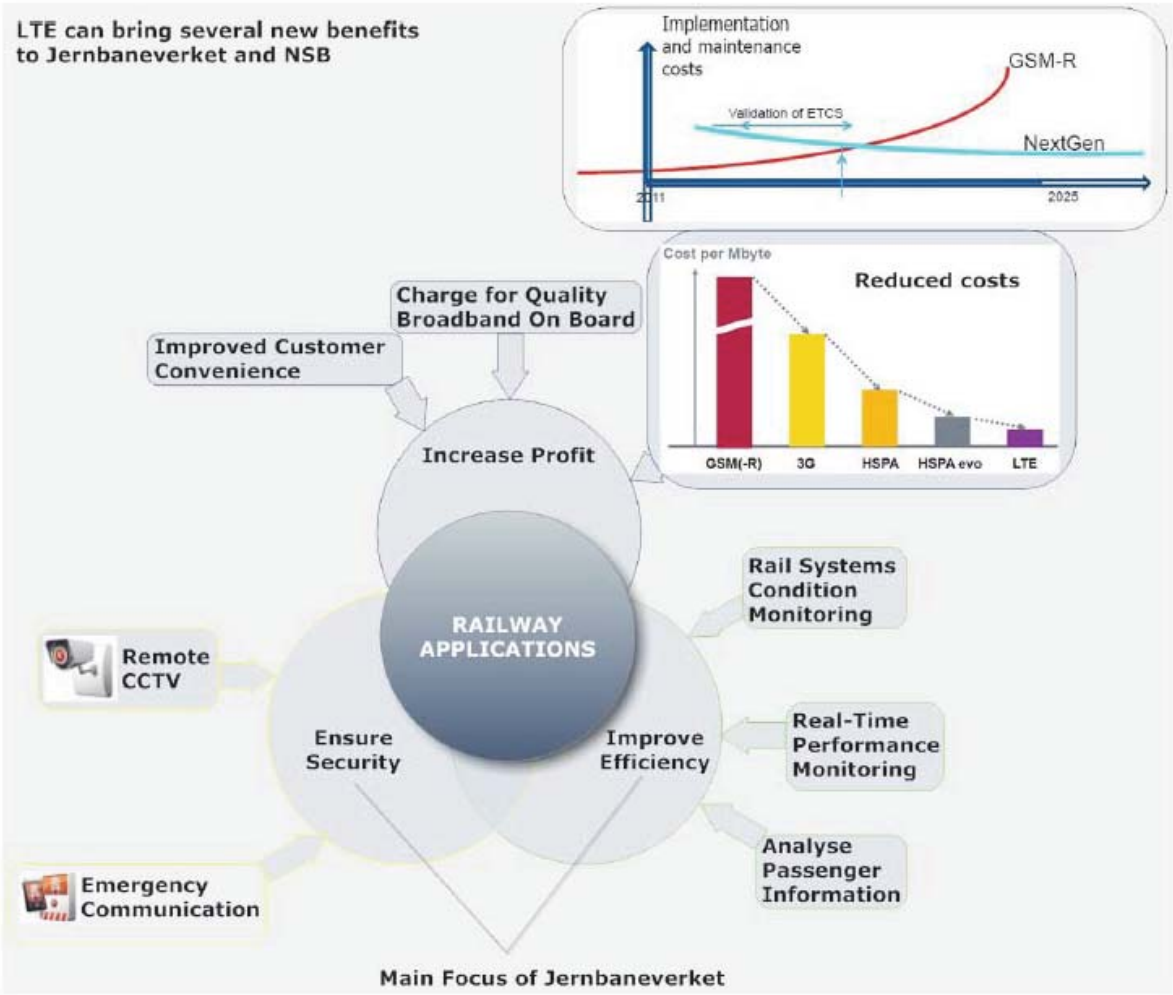


Figure 4.1: LTE Applications. [21] [22] [23] [24]

From: www.diva-portal.org/smash/get/diva2:644985/FULLTEXT01.pdf

As outlined in the NEC plan study, we propose use of multi-MHz M-LMS spectrum with LTE, along with AMTS (as well as low band VHF we also hold nationwide) for NEC advanced railroad wireless for (i) passenger train operations, and (ii) for the foundation of full-coverage, robust high-speed wireless access for passengers.

From Nokia Siemens Networks “LTE for railways” September 2010

Solve your business challenges and achieve environmental benefits

Broad band on Trains

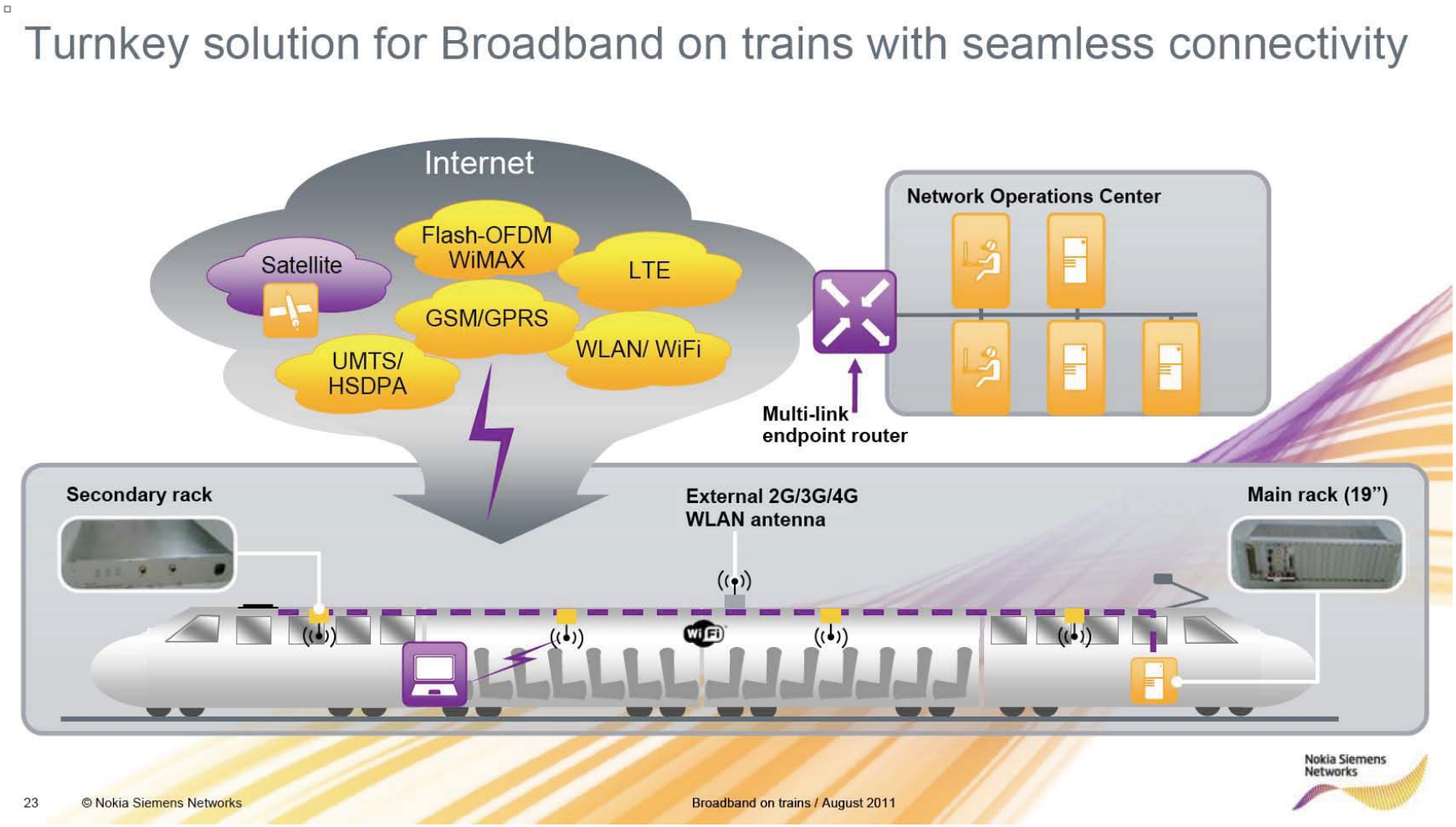
© Nokia Siemens Networks

LTE for railways / September 2010

Nokia Siemens Networks

From: http://www.conferinte.clubferoviar.ro/infrastructure_development/wp-content/uploads/2012/prezentari/danijel%20kuti%20(2).pdf

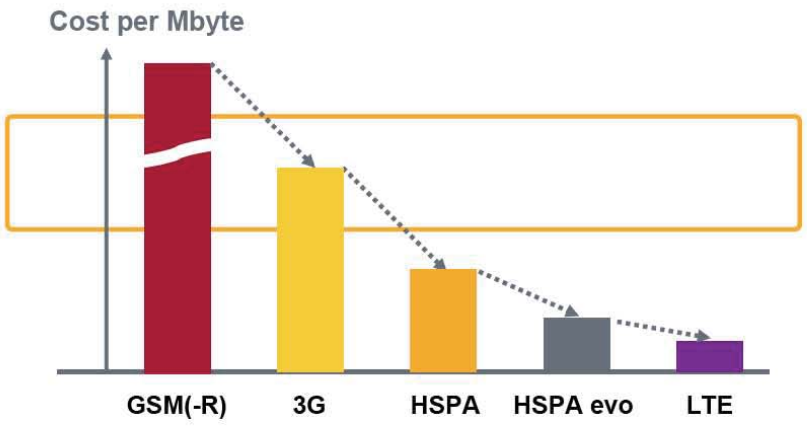
From same publication



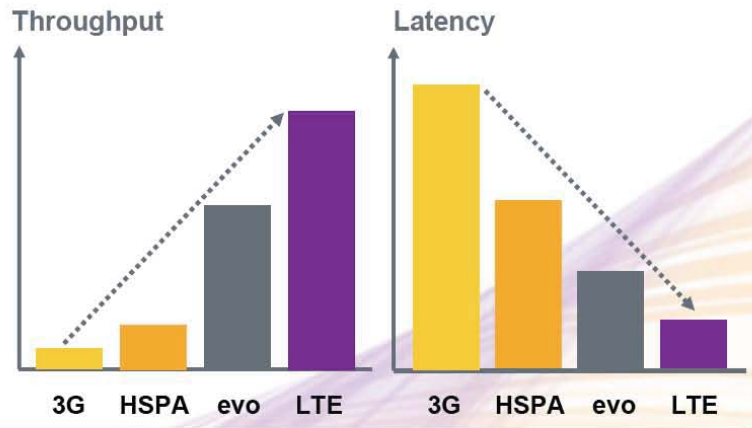
From same publication

LTE offers many benefits & the needed bandwidth for new services

Lower cost for operators



Better performance & user experience



Investment protection & fast rollout:
Re-use of existing sites, infrastructure, backhauling and frequency bands

© Nokia Siemens Networks

From same publication

LTE network structure: advanced configuration & supervision e.g. Self Organizing Networks

Self-healing

- Automated preventive corrections
- Minimized revenue loss

Self-optimization

- Optimal use of capacity
- Maximized revenue flow

Self-configuration

- Automated BTS/eNB deployments
- Faster roll-out

Quality

OPEX

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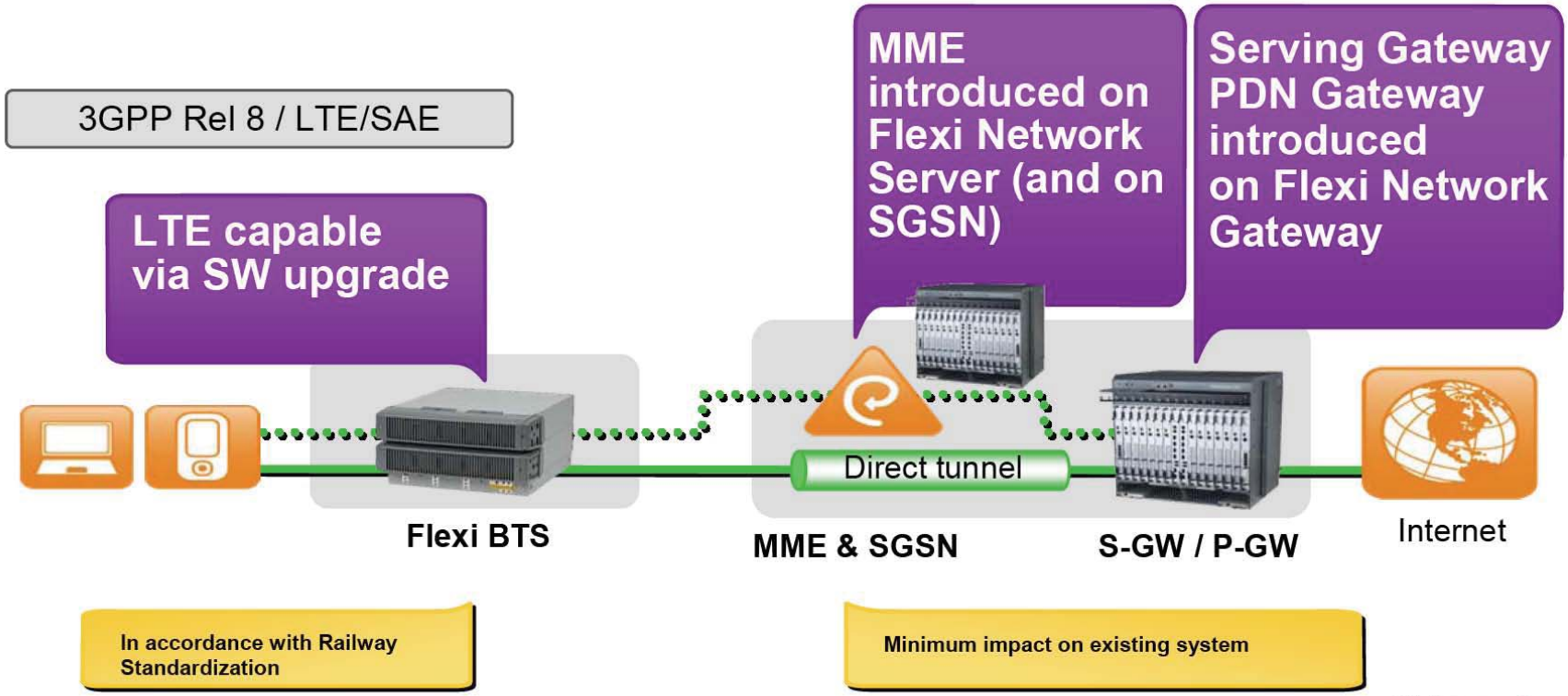
From same publication

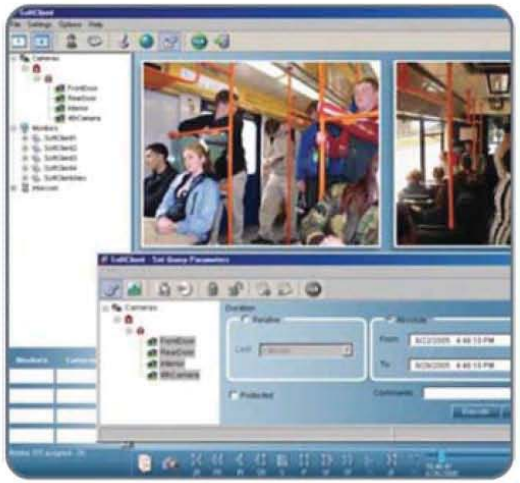
Future evolution – smooth network evolution



18 © Nokia Siemens Networks

From same publication

CCTV video surveillance promotes safety and security



- Real-time images
- On- and off-board recording
- Automatic video analysis and alarms
- Integrated positioning can trigger recordings
- Alarms to on-board staff or network controllers

*) CCTV: Closed Circuit Television

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From same publication

From same publication

Travelers prefer non-stop broadband Internet experience via WLAN

© Nokia Siemens Networks

From same publication

Real-time passenger information for all kind of public transport

updated via
GPRS/GSM-R

- Advertisements
- Travel infos
- Movies

© Nokia Siemens Networks

Nokia Siemens Networks

From SELEX (Italy) brochure: "The Operational and Mission critical – from narrowband to broadband"

SELEX Elsag's LTE network solution fulfills the requirement for a broadband mission and operational critical network based on LTE standard. It is totally integrated and interoperable with professional and civil networks.

SMART CITY AND TRANSPORTS

Network architectures used in Smart Cities foresee the use of a mix of networked technologies. Wireless broadband communications are among the most frequently used, thanks to their ability to support applications and services on the move. Video streaming, intensive access to data bases and multi-media communications between security operators benefit from SELEX Elsag's LTE solution. The growing importance of the Internet of Things and machine-to-machine communications will increase the use of fast and cost-effective LTE-based deployable solutions.
Both in urban transportation and in high-speed lines, the transmission of reliable data and video communication are becoming increasingly important.

- Reliable broadband connections to support **info-mobility applications, passenger information systems and on-board video surveillance.**
- Network resilience and broadband connections to support **real-time control data and machine-to-machine data.**
- **Broadband data:** live video feed needs to be exchanged between field personnel and control rooms.
- **Integration of networks:** different organizations need to communicate with each other in voice and data both during day-by-day activities and in emergency situations

From: http://www.selexelsag.com/internet/localization/IPC/media/docs/THE-RADIO-COMMUNICATIONS-NEW-PATH.pdf

From publication identified on the right

ALCATEL-LUCENT LTE-BASED TWC SOLUTION FOR RAILWAY OPERATIONS

Next-generation communication network technologies like LTE will transform the current ICT infrastructure for train-to-wayside communications (TWC). This transformation will lead to new operational service capabilities and improved operational efficiency.

Why LTE?

The key value propositions of LTE are summarized below:

1. With a user-plane latency as low as 10ms LTE supports a more capable CBTC system, leading to higher efficiency in train operation.
2. Sophisticated QoS built into LTE guaranteed delivery of critical traffic over a multi-service network, leading to OPEX reduction.
3. The all-IP architecture and superior broadband capacity performance of LTE opens up the possibility of supporting new kinds of operational or infotainment services and lowers the integration barrier.
4. As the leading-edge mainstream mobility technology, LTE offers a platform for future evolution and growth. Its strong ecosystem support will deliver the best possible performance–value ratio in the long term.
5. LTE is a commercial off-the-shelf solution (COTS). It does not need to be modified to meet the stringent requirements for carrying mission-critical services.
6. Despite its status as the newest of the 3GPP standards, LTE's evolutionary nature shares the benefits of many of the proven mobility technologies and architectural concepts defined in preceding standards. A January 2013 LTE market summary by the Global Mobile Suppliers Association (GSA) projected that 234 commercial LTE networks would be in place in 83 countries by the end of 2013.*

This & following pages are from:

Alcatel·Lucent

LTE FOR METRO RAILWAY OPERATIONS

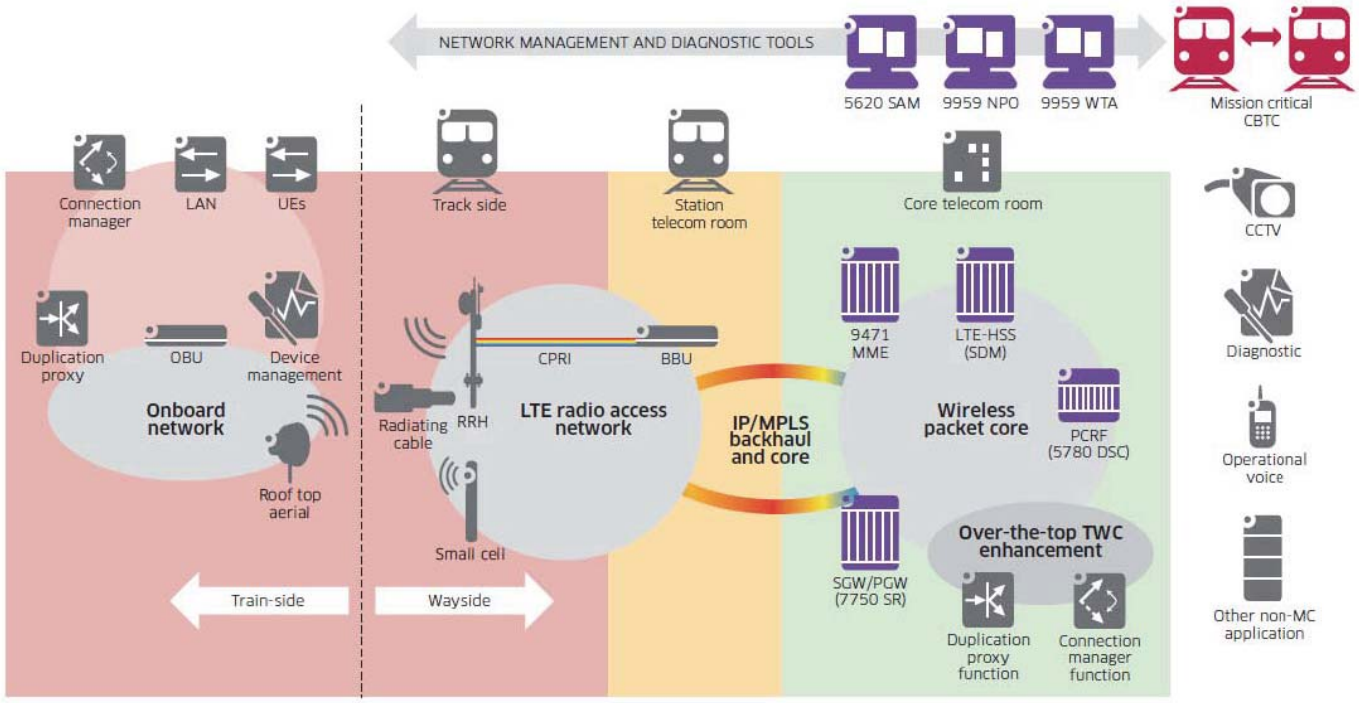
UNLOCKING NEW OPPORUNITIES TO OPTIMIZE RAILWAY OPERATIONS WITH LTE-BASED TRAIN-TO-WAYSIDE COMMUNCATIONS TECHNOLOGY

TECHNOLOGY WHITE PAPER

From: http://www.tmcnet.com/tmc/whitepapers/documents/whitepapers/2013/8272-alcatel-lucent-lte-metro-railway-operations.pdf

Continued from previous page- same publication

Figure 1. Overview of the Alcatel-Lucent LTE-based TWC solution



Small cell solutions for future railway applications

A small cell solution differs from the traditional macro cell architecture because it offers lower radio power (<5 W) output that results in smaller cell coverage. It can also integrate the baseband processing unit (BBU) and radio amplifier component within a single unit that is small in dimension (<20 L) and light enough (<20 kg) for a single installer to handle. Gigabit Ethernet backhaul is supported by way of a built-in BBU.

Another small cell differentiator is the ability to support self-organizing network (SON) capabilities. These capabilities greatly simplify radio commissioning compared to macro cell commissioning, which traditionally requires highly skilled radio planners and drive testing. With small cell deployments, an installer can be sent to the field, and commissioning can be managed remotely. This could significantly reduce commissioning time and limit disruption of train services.

OVERCOMING BARRIERS TO SECURING LTE SPECTRUM

Despite many promising benefits of LTE, a key prerequisite for adopting LTE in railway environments is to secure the necessary licensed spectrum.

The demand for LTE spectrum by the public mobile telecom industry is very high. As a result, the expectation is that it would be very difficult for a railway operator to compete with the mobile network operators to secure "sweet spot" frequency bands such as the 800 MHz–2.6 GHz bands.

[Including lower 900 MHz, which is in the standard LTE "Band 8."]*

Alcatel-Lucent believes that a number of options are available for consideration by metro railway operators. For example:

- A metro operator could use LTE 400 MHz, which provides alternative spectrum that can carry mission-critical traffic.
- A metro operator could adopt mobile virtual network enabler (MVNE) role in which it:
  - Establishes spectrum partnerships with MNOs for leasing spectrum usage rights for DTP tracks, lines and stations
  - Builds and manages the wireless network to ensure that it meets the key performance indicators (KPI) for railway operations
  - Resells or leases out spare data capacity to MNOs

This strategy establishes cooperation between MNOs and the metro operator. Both sides can share costs, maximize the investment return and avoid the complexity inherent in deploying multiple wireless infrastructures to fulfill similar needs.

Continued from previous pages - same publication

** SkyTel's M-LMS spectrum is in this spectrum "sweet spot" especially for long railway and other transportation corridors such as the US Northeast Corridor and its spurs.*

Frequencies listed below in blue are *SkyTel* entities' nationwide licenses' frequencies, including in Northeast Corridor.
Together, these are ideal for coverage, redundancy, two-way and one-way broadcast.

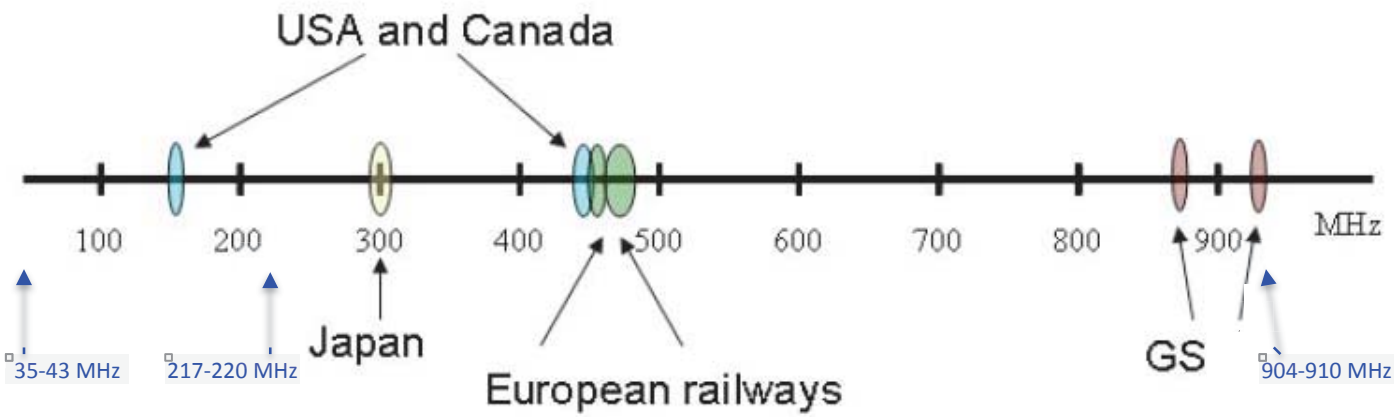


Fig. 5. Worldwide dedicated frequency bands for railway wireless communication services.

Chart above (without the blue items) is from:
http://www.researchgate.net/publication/224116357_Multi-broadcast_communication_system_for_high_dynamic_vehicular_ad-hoc_networks/file/32bfe51248be214110.pd

- 5 -

Security

Deficiencies in one-band, one-mode PTC systems vs. multi-mode ARW

(multiple spectrum bands,

both one-way broadcast and two-way wireless,

multiple over-the-air protocols, and

redundant means for delivering and verifying data integrity:

i.e.

Positive Train Control data, and GPS, can be jammed and spoofed, and derailed

in PTC stand-alone wireless far more often and easily

than in SkyTel's proposed Advanced Railroad Wireless.

U.S. Department of Transportation
Federal Railroad Administration

https://www.fra.dot.gov/Page/P0152

Program Areas

Train Control

Positive Train Control

- PTC Overview
- PTC Development
- PTC Analyses
- Incremental Train Control System
- North American Joint Positive Train Control
- PTC Testing & Evaluation

Positive Train Control (PTC) Information (R&D)

Positive Train Control (PTC) systems are integrated command, control, communications, and information systems for controlling train movements with safety, security, precision, and efficiency. PTC systems will improve railroad safety by significantly reducing the probability of collisions between trains, casualties to roadway workers and damage to their equipment, and over speed accidents. The National Transportation Safety Board (NTSB) has named PTC as one of its "most-wanted" initiatives for national transportation safety.

PTC systems are comprised of digital data link communications networks, continuous and accurate positioning systems such as NDGPS, on-board computers with digitized maps on locomotives and maintenance-of-way equipment, in-cab displays, throttle-brake interfaces on locomotives, wayside interface units at switches and wayside detectors, and control center computers and displays. PTC systems may also interface with tactical and strategic traffic planners, work order reporting systems, and locomotive health reporting systems. PTC systems issue movement authorities to train and maintenance-of-way crews, track the location of the trains and maintenance-of-way vehicles, have the ability to automatically enforce movement authorities, and continually update operating data systems with information on the location of trains, locomotives, cars, and crews. The remote intervention capability of PTC will permit the control center to stop a train should the locomotive crew be incapacitated. In addition to providing a greater level of safety and security, PTC systems also enable a railroad to run scheduled operations and provide improved running time, greater running time reliability, higher asset utilization, and greater track capacity. They will assist railroads in measuring and managing costs and in improving energy efficiency. Pilot versions of PTC were successfully tested a decade ago, but the systems were never deployed on a wide scale. Other demonstration projects are currently in the planning and testing stages. Deployment of PTC on railroads is expected to begin in earnest later this decade.

This requires high *security*, similar to what is attempted in “smart grid” wireless to control power production and grid facilities, and advanced air-ground wireless command and control wireless. But, this is not shown for US PTC wireless, *nor is achievable with one spectrum band and one form of wireless link to a high degree*. There are no PTC wireless security protocols SkyTel has found in documentation or in law including 49 CFR Part 236, Subpart H - Standards for Processor-Based Signal and Train Control Systems.

PTC is Next ? -

Following a proud tradition of gross negligence in proper *security* engineering and implementation in vital communications including wireless systems, to name some stars:

Internet: We all know some of this.

GPS: (i) Interference: commercial receivers without proper simple filters. e.g.: the alleged Lightsquared problem. See this Javas Ashjaee short presentation: to the FCC: http://javad.com/jgnss/javad/news/pr20120910.html (ii) Spoofing: Easy to do. http://arstechnica.com/security/2013/07/professor-spoofs-80m-superyachts-gps-receiver-on-the-high-seas/ (iii) Google "GPS jamming spoofing" for more. (Military GPS is more secure, but is not available including for PTC.)

LTE: E.g., http://securityaffairs.co/wordpress/10375/security/lte-networks-vulnerable-to-jamming-a-question-of-national-security.html and http://www.crows.org/details/251-vulnerabilities-of-lte.html?pop=1&tmpl=component . LTE for private systems, such as public safety, will be more secure.

P25: For public safety (guns and hoses folks) but not secure: e.g., http://www.crypto.com/p25/ . These guys should try out US PTC - any takers?

Smart Grid: Not easy wireless security, e.g., http://d-scholarship.pitt.edu/12508/1/Smart_Grid_Infrastructure_Final.pdf

Homer Simpson: Perhaps he does nuclear plants after all, like putting them at Japanese and US coastlines sure to be hit by earthquakes and tidal waves they cannot withstand like Fukushima.

The point is security is a cost humans like to avoid, then in hindsight, the "spin" takes over.

***PTC's goal is security – it is a farce if the wireless system for this is not highly secure*. The planned PTC system cannot be, nor can GPS but for certain mission critical forms.**

Security * benefits of ARW[1] vs. PTC[2]

1. Jamming: Far less likely to be jammed. See [1] below. Easy to cheaply get high power Amateur radios on lower 200 MHz, retune, and jam PTC on 220 MHz range channels. Much harder for anyone to get sophisticated wider-band radios capable of jamming all of the multiple bands and modes of AWR.
2. Interference: Far more robust to interference. See [1] below and papers on wideband OFDM LTE, etc.
3. Spoofing and interception: Far more resistant. See [1] below.
4. Points and probability of failure: Far superior. PTC will have far less back up, if a base station or several in an area fail in mobile coverage and base-to-network links. See also [1] below.
5. Coverage redundancy: Far superior in range, overlaps, etc. See also [1] below.
6. Economic stress: Far less, since AWR is far more cost effective, and has far more economic value and future viability, better tech and equipment supplies and future, etc. See also [1] below.

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[1] AWR (Advanced Railroad Wireless) as described herein. It includes: (1) The described multiple bands, (2) OFDM subcarriers in each, and (3) where critical traffic uses all or many of these, so that if one band and some carriers are subject to jamming, interference, spoofing or corruption, failure, etc., the others will not or be less likely to suffer the same, in same times and places. (4) Also, ARW will have order(s) of magnitude more capacity and uses, justifying more base stations, and more coverage redundancy, and (5) will have highly secure one-way broadcast antenna stations, with coverage that will be hard to compromise and afford additional redundancy (for network to mobile traffic). (6) It will also support secure radio-to-radio mesh nets that will provide an additional robustness mode for mission-critical data (where if many nodes fail, the others still operate to complete connections). (7) If Meteor burst communications (MBC) is also used for some of our 35-43 MHz spectrum, this adds major additional security for reasons covered in MBC radio literature (super wide area coverage, hard to intercept, very easy to secure base stations, allows nanocencond timing and MBC-generated cryptography that can add to security, etc. MBC and terrestrial can be combined.

[2] PTC as planned by US public railroads: (1) narrow 220 MHz range channels; (2) only one or several channels per fixed base station; (3) substantial radio-service overlap (always 2 serving base stations), and (4) assuming hot-standby of radios at each based station, (5) cryptography of the essential data, (6) mission-critical grade radios and other components, (7) good physical security of the system, (8) good system maintenance, etc. (AWR will have 4-8, and vast improvements in 1-3, and other security benefits.)

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* By “security” we mean all aspects of the wireless systems that contribute to successful radio communications without any failures and compromises at any place and any time, and being able to verify that success.

This is an *example* of *analysis* of *security in a mission-critical wireless system*, provided to illustrate that it is a serious undertaking. It is not seen in US PTC wireless as noted above. This is not provided here to suggest this is a suitable security solution for PTC, and it cannot come close to matching security in the proposed ARW outlined on a slide above. *Mission-critical wireless security must be well planned and implemented, especially when the main application is security (not communications) – crash avoidance in PTC.*

Mitigating Security Threats in Tactical Networks

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ABSTRACT

The future of tactical networks encompasses multi-hop digitised voice and data communications using VHF/UHF-band radios. While this radio band has excellent propagation properties, their relatively low bandwidth, high error rates and node mobility makes tactical radios less than ideal as a robust networking platform. Since networking is new to tactical communications, the security implications are not fully understood. Significant related research has been done for the network threats and vulnerabilities of commercial mobile ad-hoc networks (MANETs), however the threats in the literature are not always directly analogous because of the different communications characteristics. This paper takes a novel approach by reviewing known MANET security threats and then evaluating their potential impact on tactical networks. Though this analysis does not cover all possible security threats, it does leverage previous work and identify the most critical areas for further research. Based on this analysis, we propose the use of a cross-layer service framework to integrate security functions across all communication layers. A description of the framework and its application to several security areas are included.

Table 1: Qualitative Risk Analysis for Tactical Networks

Threat	*Vulnerability*	*Impact*	*Risk*	*Primary Control*
Denial of Service	Low-High	High	Low-High	Layer specific mechanisms [1]
Eavesdrop	Low	High	Low	Cryptography [10]
Masquerade	Low	Very High	Medium	Trust System [11] and Cryptography
Modification	Low	High	Low	Cryptography
Traffic Analysis	High	Low	Medium	Traffic Obfuscation [12]

From article on preceding page.

(Analysis example only.)

2.0 THREAT CLASSIFICATION

Continued from preceding Page.

(Analysis example only.)

The key to information protection is maintenance of confidentiality, integrity and availability (CIA). Over time, a number of attacks on networks have been devised each attempting to compromise one or more of the CIA principles. These attacks can be grouped into different types of threats [7]. We consider two main types of threats for tactical networks. Passive threats are based on an attacker who does not emit energy while observing the energy transmitted from other sources. Active threats are based on an attacker who actively transmits energy.

2.1 Passive Threats

Two types of passive threats are considered here. While traffic analysis is of more critical to tactical networks security, both types of network are sensitive to eavesdropping.

Traffic Analysis: Involves an adversary who collects transmitted energy, traffic flows (protocol headers), sizes, and/or timings to gather insight into the network topology and traffic patterns. This is a serious threat in tactical networks due to their small size, wireless bandwidth and long range. Though message contents cannot be read, the relative importance of nodes and tempo of operation can be determined. Tactical networks are quite vulnerable to this threat as it is straightforward to accomplish with limited knowledge of the network being observed.

Eavesdropping: Involves an adversary who examines the content of messages to gather the information transmitted. Again tactical networks are at risk. In this case, the threat is to confidentiality. Tactical networks have a relatively low vulnerability to this threat due to the many layers of security that must be penetrated (up to the application level), but the loss of information privacy could have a significant impact.

2.2 Active Threats

2.2 Active Threats

For active threats the adversary transmits at the frequency used by the tactical network. This makes it more dangerous for the adversary as it leaves them open to counter measures (which are not discussed here).

Denial of Service: Involves an adversary who uses the transmission of packets or raw energy to deny or delay service to authorized participants. There is a wide spectrum of threats, basically one per network layer. At the physical layer, jamming raises the noise floor to the point that nodes in the vicinity cannot decode network traffic [8]. At the network layer the routing protocol might be compromised invalidating packet forwarding or spurious packets can be used to overload the available bandwidth (e.g. gray-hole and rushing [9]). All networks are vulnerable to and impacted by the loss of availability inherent in physical layer attacks. Attacks higher in the protocol stack are made difficult due to the multiple layers of security services.

Masquerade: Involves an adversary who emulates or acquires one or more valid nodes within a network in order to perform an attack (e.g. wormhole and sybil [2]). This threat is relatively unlikely in tactical networks where the possibility of creating or capturing (and then successfully using) a compatible platform is limited. There is however a significant impact on confidentiality and integrity if such an attack were successful as critical information transmitted could be collected, and potentially modified (see below).

Modification: Involves an adversary who alters the content (e.g. node exposure and route manipulation [9]) of an intercepted message and then passes it on. The adversary must be an authenticated member of the network in order to accomplish this. A masquerading node is capable of modification up to and including at the application level. Due to the multiple levels of security at each layer, tactical networks are unlikely to be compromised at a high enough level to interfere with the confidentiality and integrity of the network. Compromised availability is the mostly likely result of this type of threat.

Continued from preceding Page.

(Analysis example only.)

- 6 -

SkyTel

AMTS 217 - 220 *MHz*
M-LMS 904 - 910 *MHz*
& Lowband 35 / 43 *MHz*

For nationwide
smart transport, energy and environment systems
which can include ARW

SkyTel FCC Licenses

900 MHz wide-block M-LMS, ˜80+% of US, 6 MHz total, held by:
Telesaurus Holdings GB LLC, Skybridge Spectrum Foundation
(Renewal applications pending)

900 MHz Part 22 and MAS, ˜99% of the US, held by:
Skybridge Spectrum Foundation, V2G LLC, Intelligent Transportation & Monitoring Wireless LLC

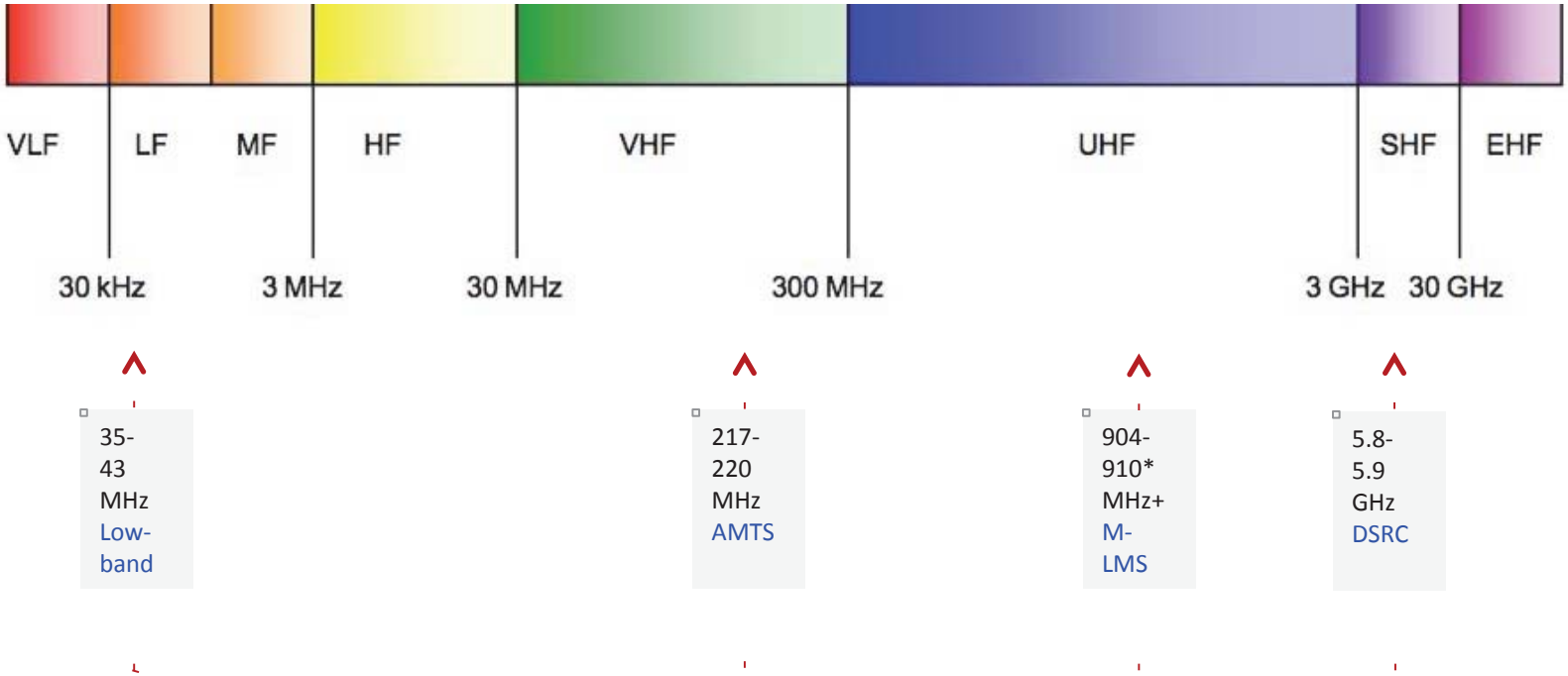
200 MHz AMTS, ˜95% of US, 1-2 MHz total, held by:
Environmentel LLC, Verde Systems LLC, Intelligent Transportation & Monitoring Wireless LLC,
Skybridge Spectrum Foundation
(Potentially others under pending FCC proceedings.)

43 and 35 MHz, ˜99% of US two-way, and 100% one-way, 300-600 kHz total, held by:
V2G LLC, Environmentel LLC, Intelligent Transportation & Monitoring Wireless LLC,
Skybridge Spectrum Foundation

The licenses described herein may be confirmed via the FCC's online databases by going to the following link, clicking on the "Advance License Search" section and then entering in the Licensee's name in the licensee-name field. http://wireless2.fcc.gov/UlsApp/UlsSearch/searchLicense.jsp

Following pages do not further describe the MAS and 220 MHz licenses: see FCC ULS.

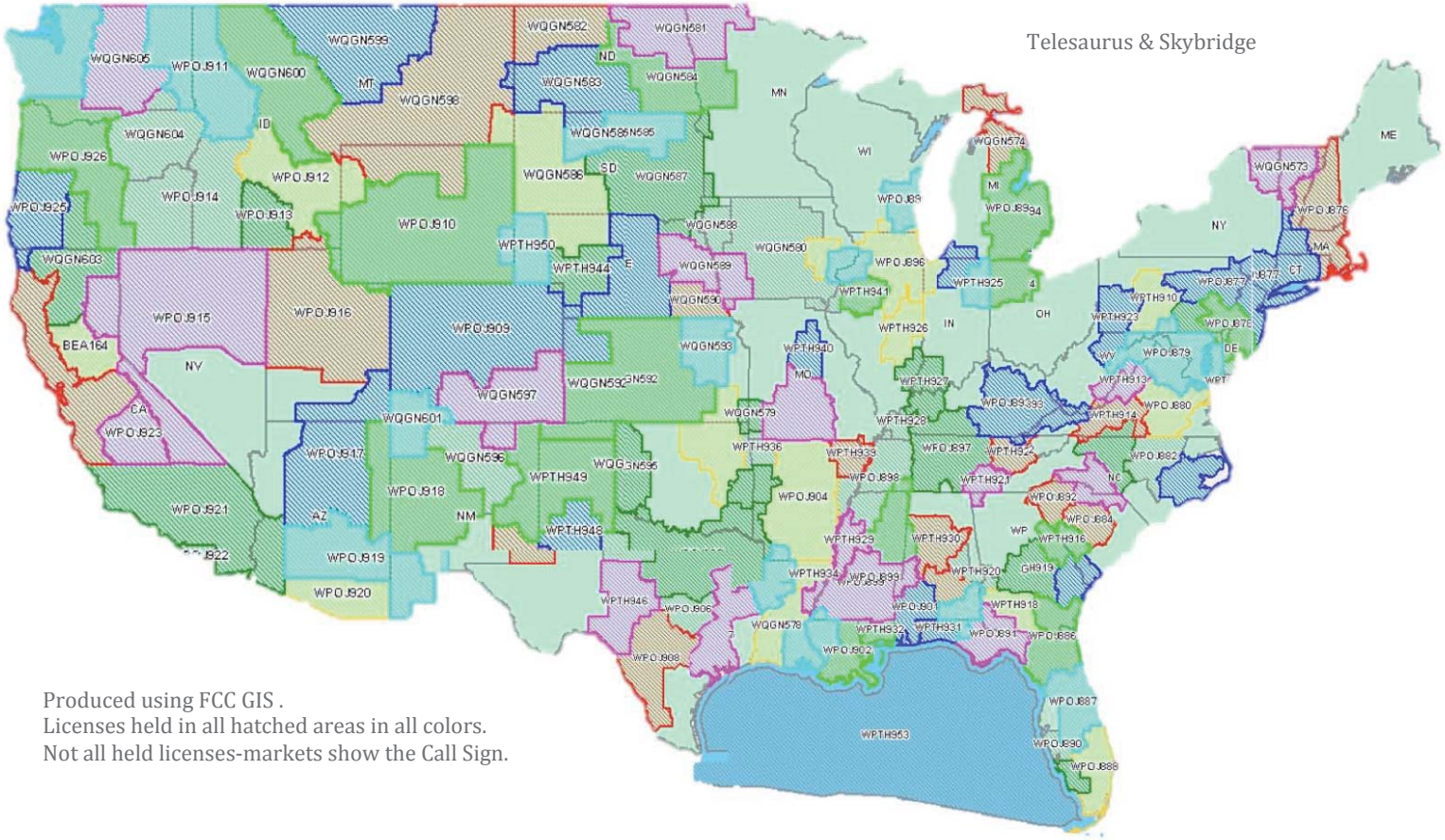
SkyTel FCC licensed spectrum, and other bands available for ARW – location in radio spectrum ranges



(A deployment architecture using this spectrum is depicted 4 slides below.)

* Additional N-LMS spectrum, up to 14 MHz additional, can be used with the M-LMS for Intelligent Transport System (ITS) and synergistic applications. N-LMS uses relatively low-height base stations. M-LMS can use any antenna height. The two can be combined for ITS and related applications. We depict this in a slide below.

M-LMS A-block Licenses, *6 MHz* bandwidth in lower *900 MHz*. See preceding page. This spectrum is within 3GPP *LTE Band 8*.

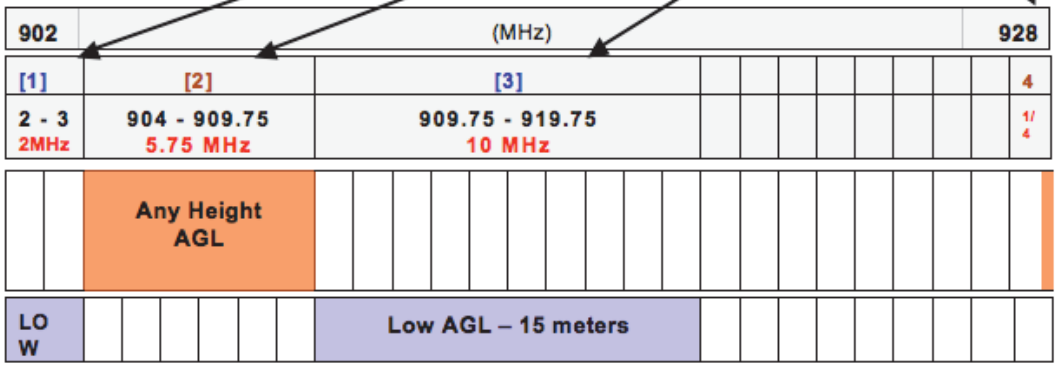


Produced using FCC GIS .
Licenses held in all hatched areas in all colors.
Not all held licenses-markets show the Call Sign.

Note: below depicts the M-LMS and N-LMS sub bands. We do not have to use the channelization depicted in the second table below. We can use any channelization.

LMS Spectrum

AGL Max	ERP Max	Spectrum	[1] N-LMS	[2] M-LMS A-block Wide Subband	[3] N-LMS	[4] M-LMS A-block Narrow Subband
m	W	MHz	Gov partner	Held	Gov partner	Held
15	30	902 – 904	N			
Any	30	904 – 909.75		M		
15	30	909.75 – 919.75			N	
		Not Available				
Any	300	927.75 – 928				M



http://www.scribd.com/doc/36614169/Sky-Tel-Atlis-900-200-40-MHz-for-Smart-Transport-Energy-Environment-V3-9-10-Public#download

Use of TD-LTE in this M-LMS spectrum is described in a study funded by SkyTel by Dr. Nishith Tripathi, submitted to the FCC, a copy of which is here: http://www.scribd.com/doc/104580013/LTE-for-M-LMS-900-MHz-for-Intelligent-Transportation-Systems-N-D-Tripathi-Aug-2012

SkyTel plans to use *TD-LTE* in this "LMS" spectrum.

Telesaurus Holdings GB LLC and Skybridge Spectrum Foundation hold M-LMS A-Block licenses in the areas depicted on the following map.

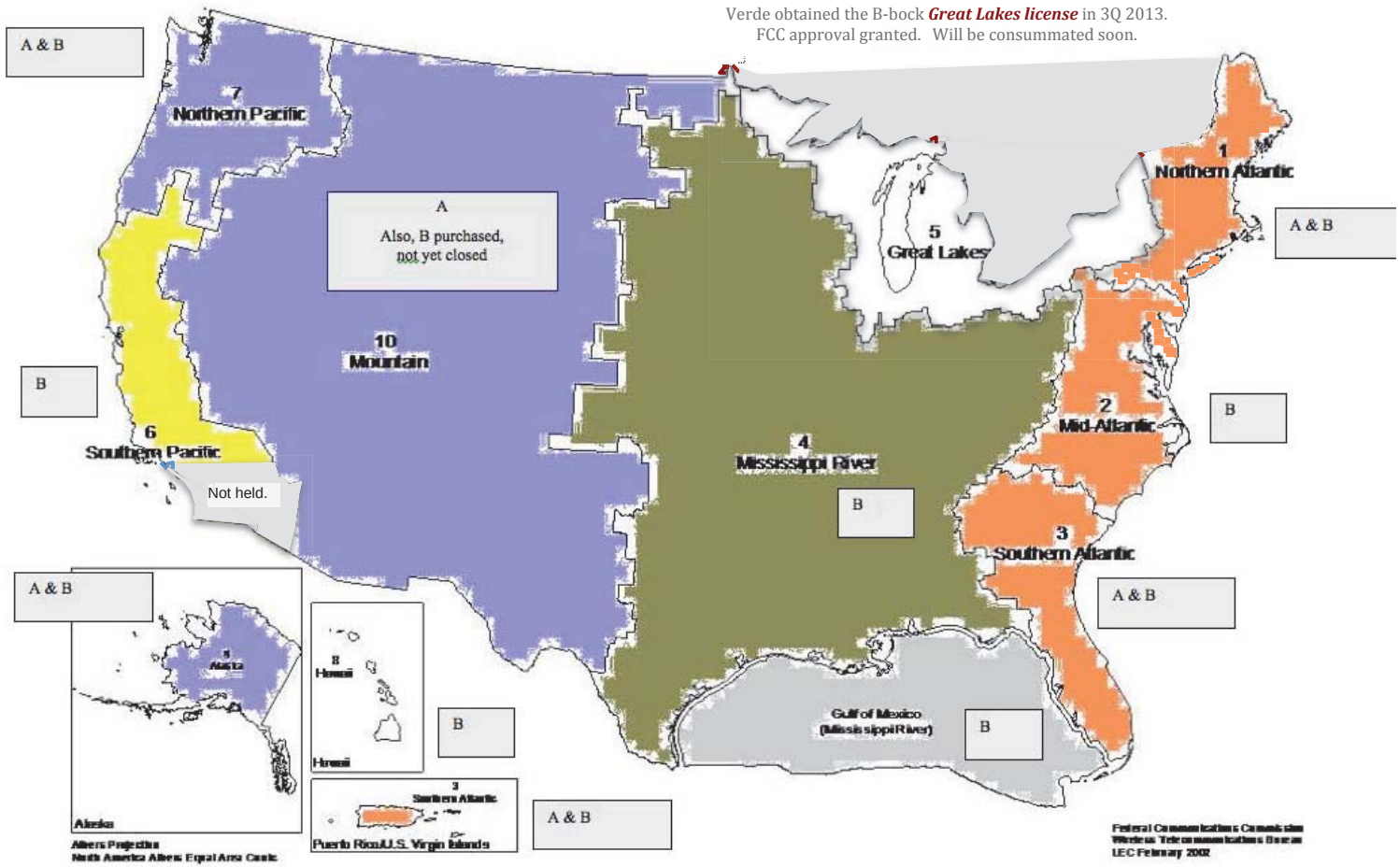
In joint ventures with State and/ or local government, Skybridge may also obtain use of FCC licenses for any region in which the hold M-LMS licenses for N-LMS spectrum depicted above, as well as in the other regions.

The SkyTel entities may also use substantial amounts of 5.9 GHz DSRC spectrum, in the range of 20-30 MHz, under Part 90, Subpart M (this is the sister ITS band to LMS). Cisco bought an Australian company advancing

Among other uses: vehicle to vehicle, and vehicle to roadside (in dual mode with other spectrum indicated above), but also point-to-point backhaul (5.9 GHz, in P-t-P use, matches in distance LMS in mobile use).

AMTS Licenses, *1 MHz* bandwidth in each block, in lower *200 MHz*.

Licensees: Environmentel, Verde Systems, Skybridge Spectrum Foundation, and Intelligent Transportation…Wireless.

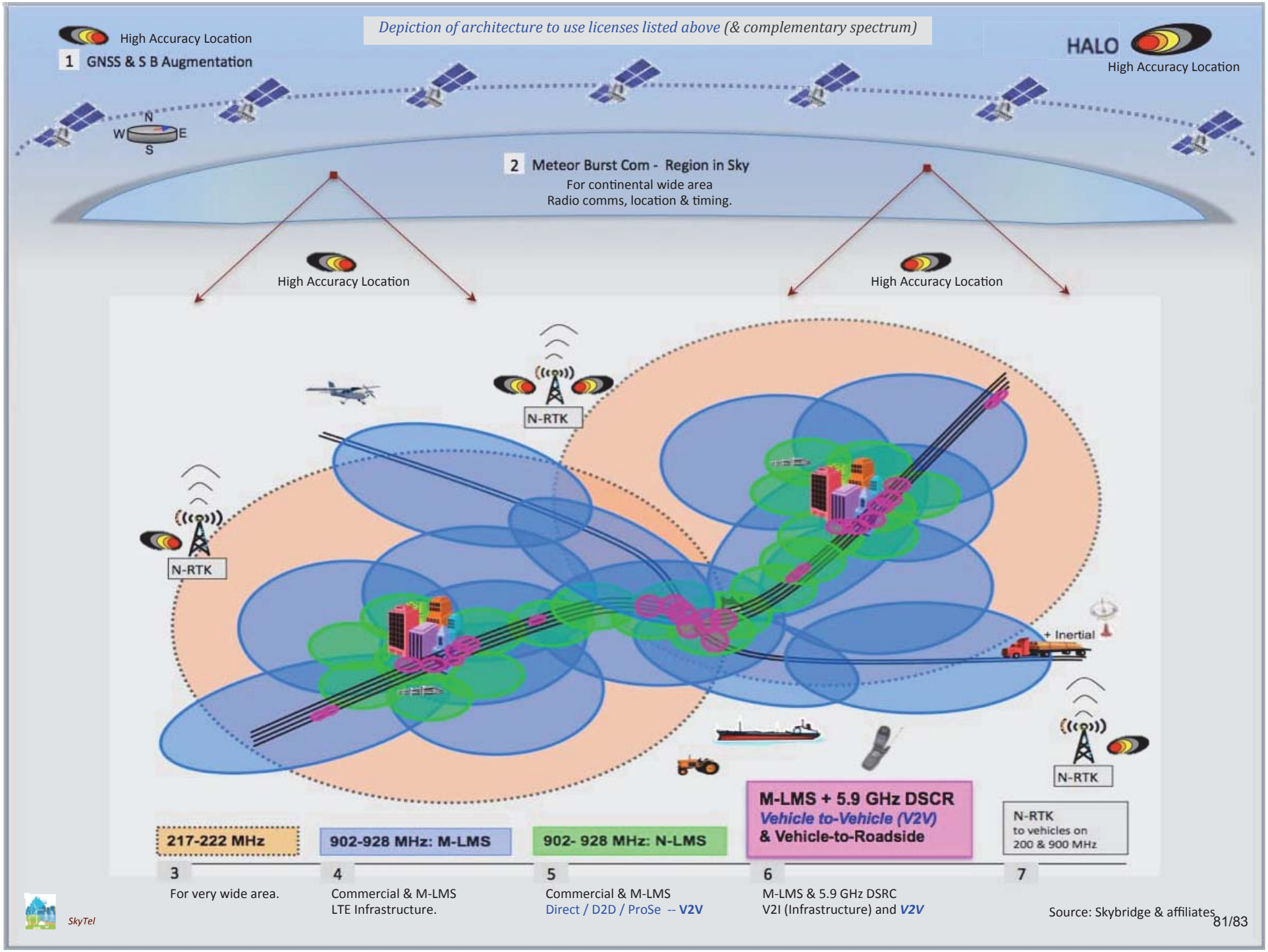


Note: some of the spectrum (one half or less of total) in parts of market areas 1 and 7 have been sold-assigned to power utilities (as of 1Q 2013).

~ 4,000 *35 MHz and 43 MHz* licenses, *20 kHz* in each, ~*300-600 kHz total,* in all parts of the US.

Licensees: V2G, Skybridge Spectrum Foundation, Environmentel, Intelligent Transportation…Wireless LLC.

The licensees hold *in all of the nation* this spectrum in license areas shown below.



Source: Skybridge & affiliates

End Notes

End Notes. These items further support certain components presented above.

1. From NJ State Rail Plan, Draft Final Report, October 2013

Unfunded Regulatory Mandates and Compliances

In response to several fatal passenger train accidents, Congress passed legislation significantly affecting railroad operations. While the actions were intended to improve safety, they have introduced additional operating costs:

- Positive Train Control (PTC) - positive train control is a group of technologies that automatically adjusts train speeds to avoid accidents caused by human error. It is designed to prevent train-to-train collisions, speed-related derailments, unauthorized incursions by trains onto sections of track where maintenance is being performed, and movement of a train through a track switch left in the wrong position. Installation of PTC is expected to cost $225 million.
- Hours of Service Rule Changes - new laws have been passed affecting rest periods for engineers and conductors. The laws will require additional crews because of the increase in rest times. Compliance with these changes will require NJ TRANSIT to increase its labor force to maintain existing service levels.

2. From NJ State Rail Plan, Draft Final Report, October 2013

Funding and Appropriate Investment Models

With the limitations on funding at all levels of government, new sources of monies to support investment and operations need to be identified or developed. An innovative funding framework is required that attracts resources from both the public and private sectors and allocates risks.

There is a need for a new funding model that appropriately reflects return on investment in public facilities. Benefits and risks of investing in particular transportation projects should be evaluated in a rational manner with information about the specific public benefits expected as a result of the investment. In this way the appropriate benefit and risks can be assigned to the right parties and this may lead to more interest in funding transportation projects from the private sector or from new public sector sources.

3. US DOT, "Nationwide Differential GPS… Assessment, Dec. 4, 2013

- U.S. Department of Transportation
  - No Federal Railroad Administration requirement for NDGPS to implement Positive Train Control

4. E. Hamberger, AAR before US Senate, June 19, 2013

Freight railroads have enlisted massive resources to meet the PTC mandate. They've retained more than 2,200 additional signal system personnel to implement PTC, and to date have collectively spent approximately $3 billion of their own funds on PTC development and deployment. Class I freight railroads expect to spend an additional $5 billion before development and installation is complete. Currently, the estimated total cost to freight railroads for PTC development and deployment is around $8 billion, with hundreds of millions of additional dollars needed each year after that to maintain the system.

AAR (freight railroads: PTC 220 LLC primarily) which are large commercial, profitable enterprises, inform the public - the US Senate - that they are using "their own funds on PTC" -- as opposed to – 'sure wish this mandate came with public funds… like our rights of way…'

US private for-profit "*critical infrastructure* often takes the positions that – we are too critical to fail, so the public must pay for our burdens if we need it, or else lose the service we provide.

They even ask the government to take others' private property, using eminent domain, for their "critical" money making - as they do regarding more 220 MHz spectrum via FCC "reallocation."

As the above presentation also presents, it appears that the Native American protection matters that arose with regard to new base stations for PTC, was a cause for a new Thanksgiving, as it became a basis to delay the unwanted mandate. "We come in PTC peace…."

SkyTel challenges AAR and its members, as well as governmental railroads, to act in the public interest in planning and deploying efficient and effective Advanced Railroad Wireless, not wasteful stand-alone PTC. *It appears they will not do so except by outside leadership, taxpayer concerns, and new Federal government requirements.*