Emerging Wireless Services, Small / Nanocells and Spectrum Sharing

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Briefing Provided For:
Committee On Radio Frequencies

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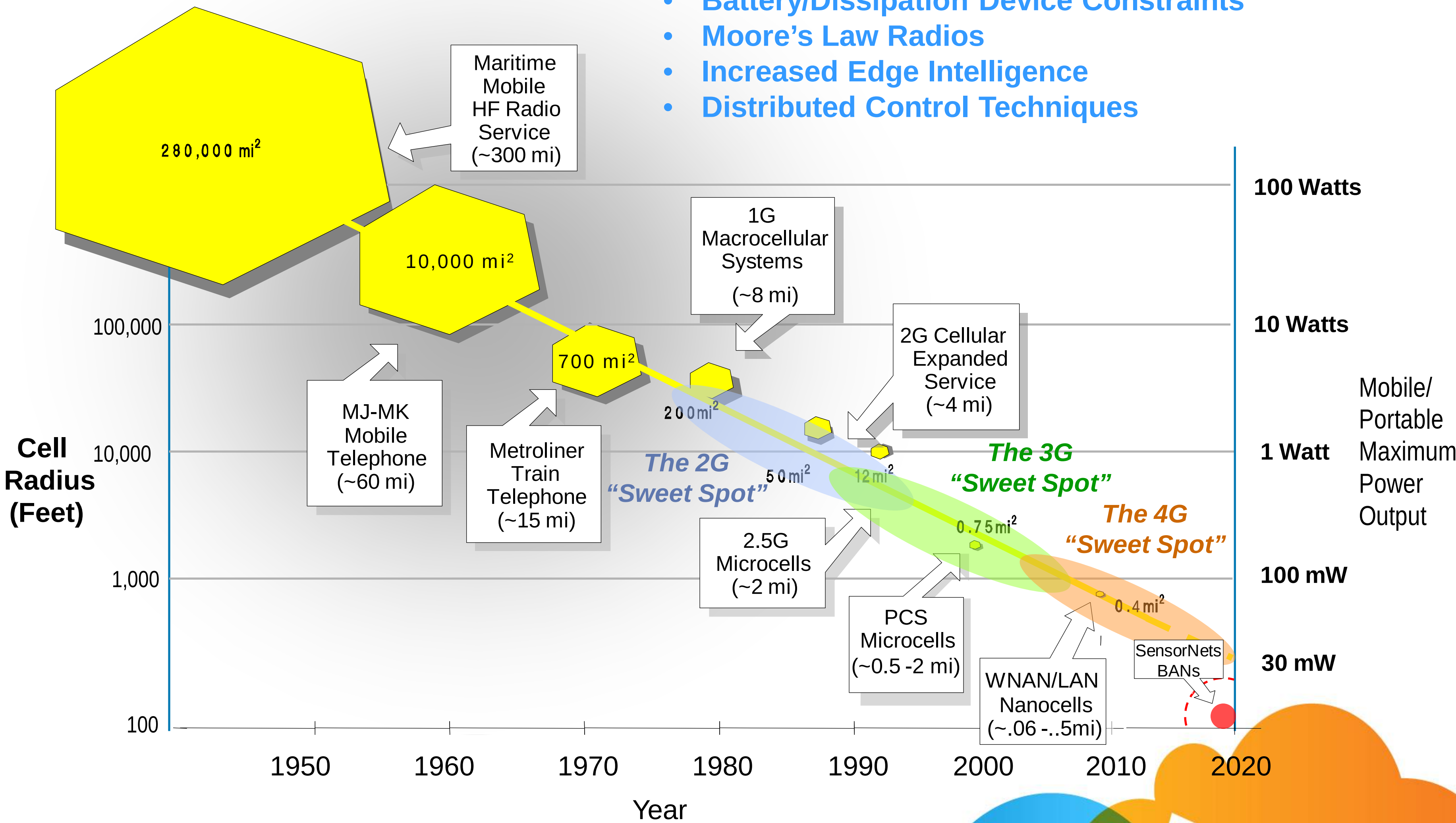
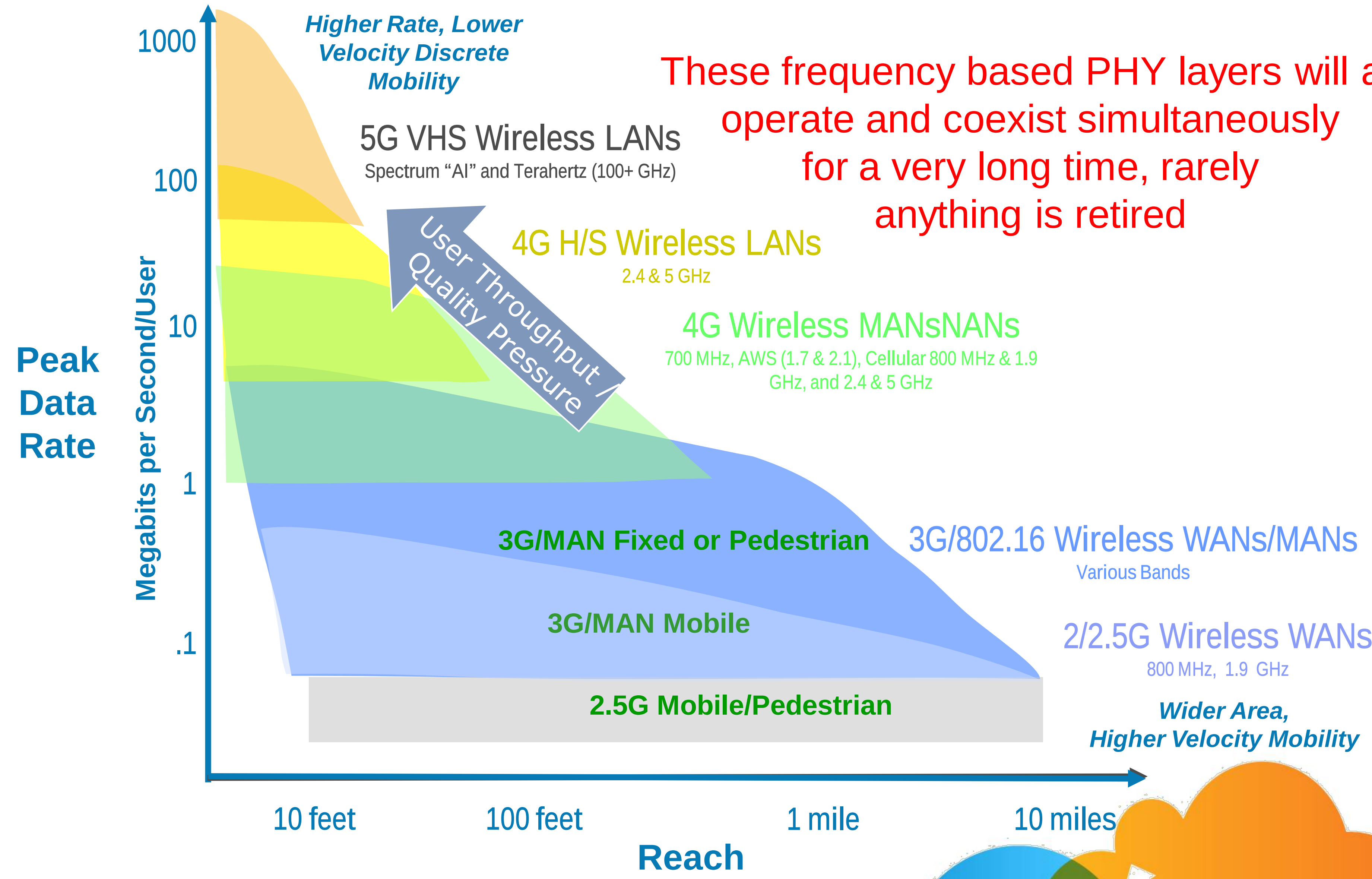
Rethink Possible

The Incredible Shrinking Cell

- **Increased Bandwidth Demand/User**
- **Battery/Dissipation Device Constraints**
- **Moore's Law Radios**
- **Increased Edge Intelligence**
- **Distributed Control Techniques**



Choosing The Right "Shannon Tool" for the Wireless Job



These frequency based PHY layers will all operate and coexist simultaneously for a very long time, rarely anything is retired

Spectrum future -Envisioning Interactive Sensor “Clouds”

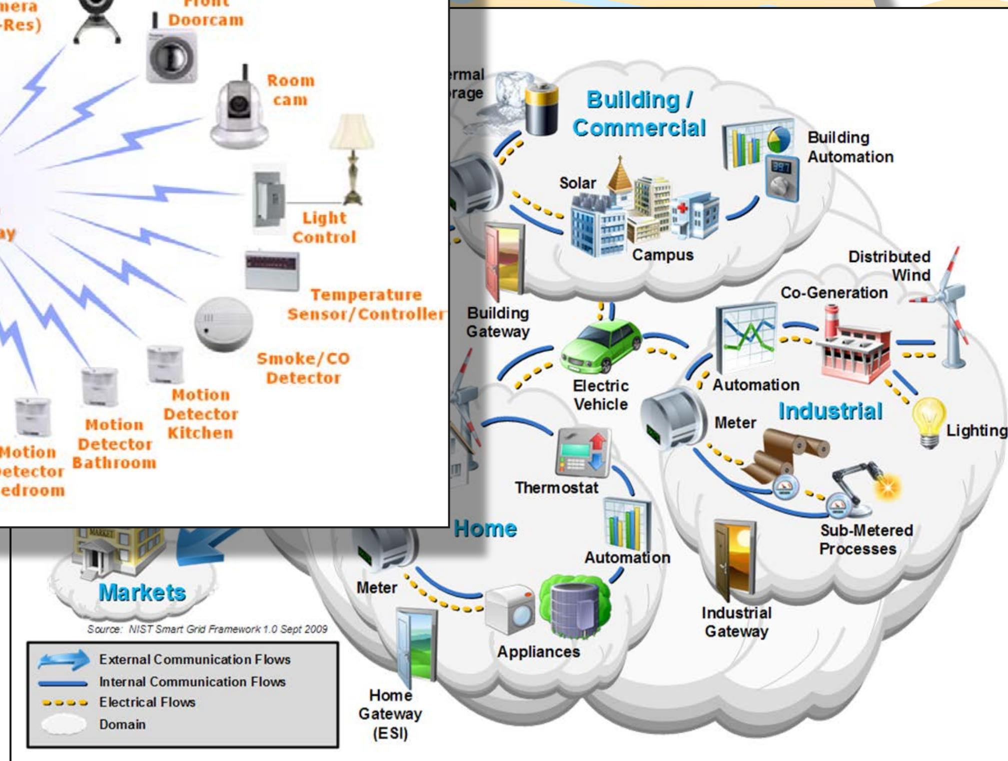
Cellular Wide-Area, Wi-Fi and Broadband Network Connections with Local M2M Sub-Networks

New Generation of Wireless services

Where do we find spectrum for these emerging services and industry?

Sensor Networks

Low power, low to moderate data, adhoc, and ubiquitous distribution, network and peer to peer



Semi Smart M2M

Machine to Machine

Moderate power , moderate to large data, network centric

Adaptive, super high capacity M2M Cloud Networks

Early 2000's small "cell" Neighborhood Area Network

EcoPole installation illustrating contrast between neighborhood APs and conventional cellular base stations / towers*

*AT&T Research Florham Park Campus

Multi-Gigabit Mobile Wireless Networks:

Where are We?

- Out of necessity, wireless **service providers are beginning to meter data usage to conserve spectrum resources** in response to burgeoning demand for data connectivity.
- **Cellular networks are evolving to smaller coverage area**, higher teledensity cells to deliver more bandwidth and to reuse spectrum more intensely.
- Even with aggressive network infrastructure investment, **a new generation of users and applications are continuing to challenge wireless network capacity: "always on"** multimedia-connected individuals and sensor clouds, 3D video, and augmented reality are preparing to enter the mainstream.
- Current cellular/wireless LAN technologies and spectrum roadmaps may struggle to keep pace with emerging wireless connectivity demands and evolving user behavior. **Without new spectrum and network architectural approaches** it is unlikely that Gigabit wireless Common Air Interfaces in high teledensity areas can arise.
- **Years ago, AT&T-developed cellular microwave communications was a similar disruptive concept that spawned many technological advances.**
- **Terahertz example: "Yesterday Once More"--- the 1930's again!**
  - **Abundant bandwidth**
  - **Simple radios**
  - **Spectrum "AI" COG Radio control layer for small and nanocell wireless networks**
  - **New architectures**
  - **New applications**

Small CELL –near term

Physics, Shannon and operational efficiencies of existing cellular solutions are driving us to small cell topography's using a combination of optical fiber and mmWave backhaul and small cell LTE customer connection. These small cells will be deployed along city roads and public spaces, to optimize the capacity of the small cell customers network connection .
Small cells may use mmWave frequencies (60-100GHz), for P to P backhaul routing of customer traffic and inter-small cell management, to get ahead of and to minimize fiber costs. Reuse spectrum while scaling out the small cell network to meet rapidly growing demands for wireless data (80 fold in four years).

- Expands upon cell splitting approach to optimize local area wireless capacity. Small cells look like regular cells to the MAC control layer , but issues of rapid customer transits (small cell) and hand-off concerns may limit scalability - some level of localized edge intelligence may be required

- Small cells will need to utilize redundant wireless and fiber mesh configurations to minimize aerial conduit obstructions

- Small cells comply with existing Cellular and Wi-Fi infrastructure, as part of an OFF LOAD HetNet “shaped network” architecture

- Small cells may be deployed quickly utilizing existing lessons learned from existing standards and deployment methods, requiring a minimal industry learning curve.

BUT …….

- Small cells will require low cost high volume mmWave, solutions for network connecting backhaul.
- Small cell architecture will need to spectrally coexist with other users both active and passive within the “operational “space . But what is the operational space …….Spectrum AI?

NANO CELL – longer term

Evolving wireless network technologies and services as well as the "Shannon limit" will drive future wireless networks beyond small cells and toward the efficiencies of "shaped" wireless Nanocells networks. Networks designed to utilize mmWave and THz frequencies (above 100GHz), for both inter-nanocell backhaul as well as mobile customer connectivity.

- Conceived as a third PHY layer overlay to existing Cellular and Wi-Fi infrastructure, as part of an OFF LOAD HetNet "shaped network" architecture

- Redirects "Big Data" from Network and cellular PoP's to a parallel nanocell layer, potentially returning current data dedicated cellular spectrum back to voice applications

- Intelligent edge (small coverage area) nanocells work in concatenated clusters that follow the customer - and provide localized edge based handoffs due to mobile customers short duration within the nanocell

- Spectrum coordination between Nanocells and the nanocell-to-customer handset can be optimize for spectrum usage and service type, using COG based spectrum AI and software defined radio and mulit-band (MHZ, GHz, THz) front end radio

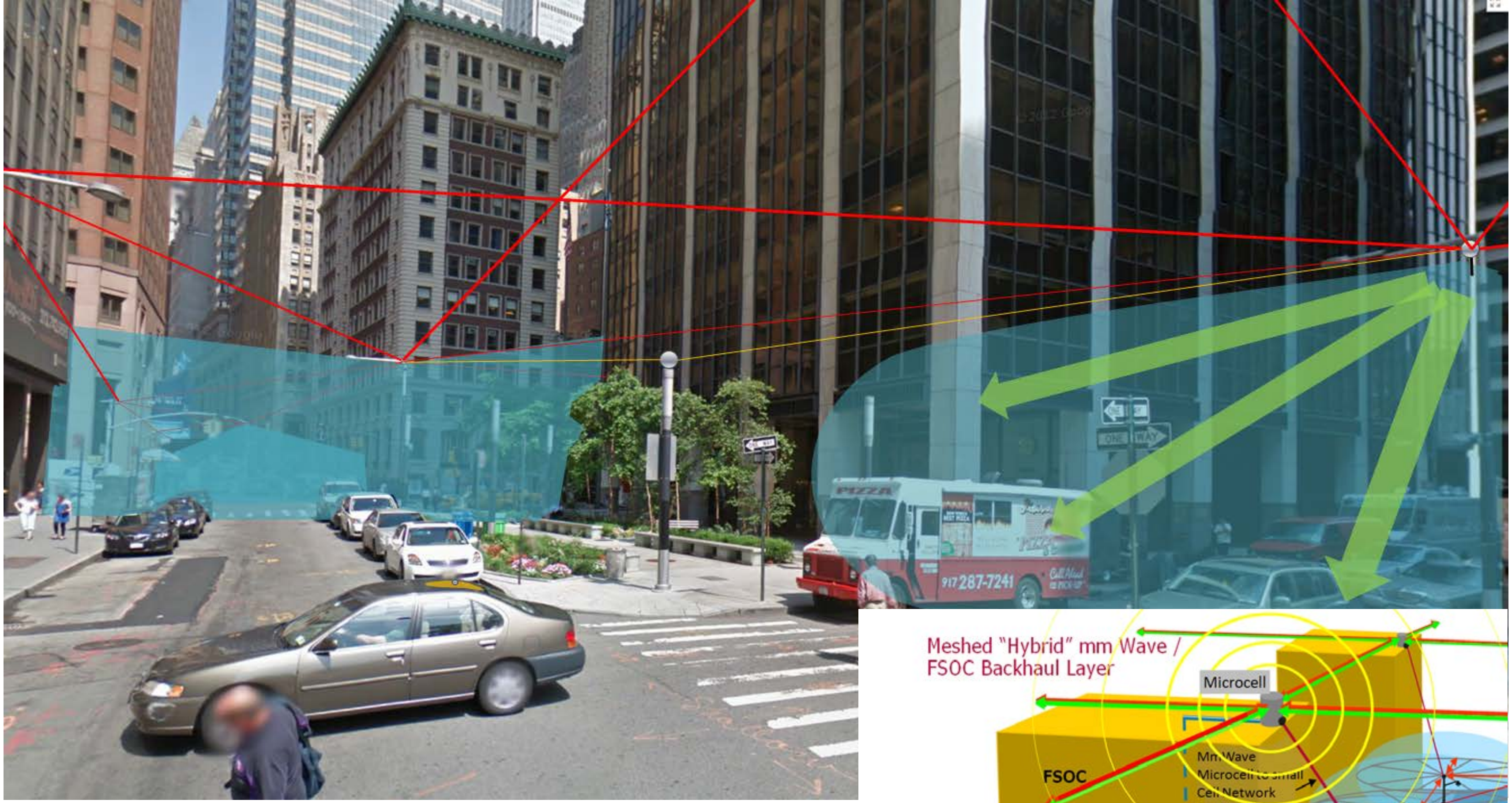
- Using high -frequency mmWave and THz spectrum , nanocell Super channels will be capable of transporting and delivering 10-100Gbps wirelessly

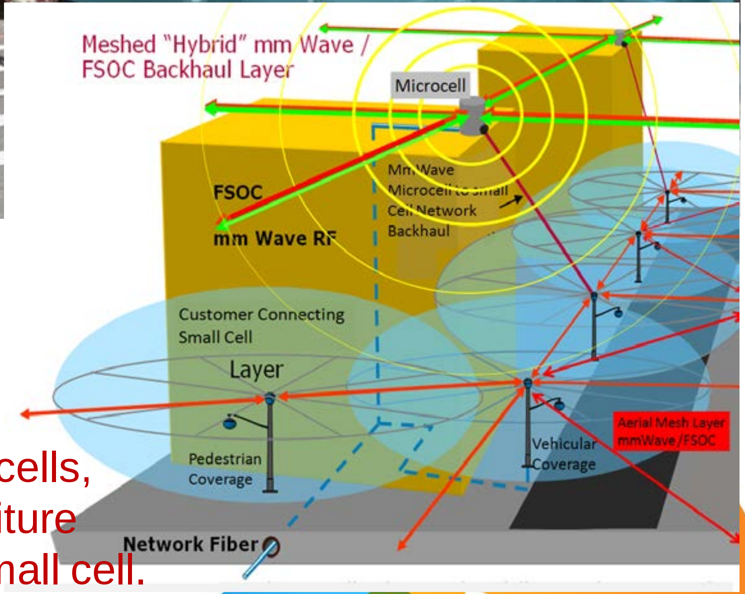
BUT …….

- MmWave, THz and optical based nanocells will require "low interference "high gain antennas and micro sectored or active beam steering to maintain dynamic link with customer and inter-cell backhaul

- Nanocell architecture needs to spectrally coexist with other local users, both active and passive, define local………..

- What lessons, if any, can be learned from existing cellular / Wi-Fi standards and practices to support spectrum sharing and coexistence?





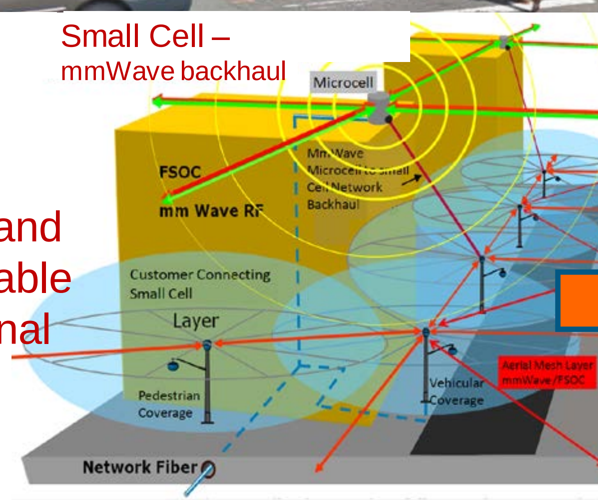
Shaped Wireless Small Cell Aerial Networks

Use the street and pedestrian areas as conduits for mmWave /FSOC wireless backhaul between small cells, and small cells mounted on AC powered street furniture to avoid costly optical fiber deployments to every small cell.

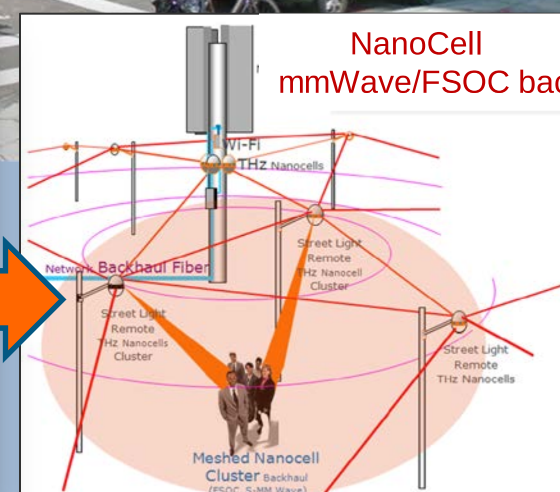
Shaped Nanocell Networks

Moving from cellular omni and sectored emission to steerable mmWave and THz directional beams

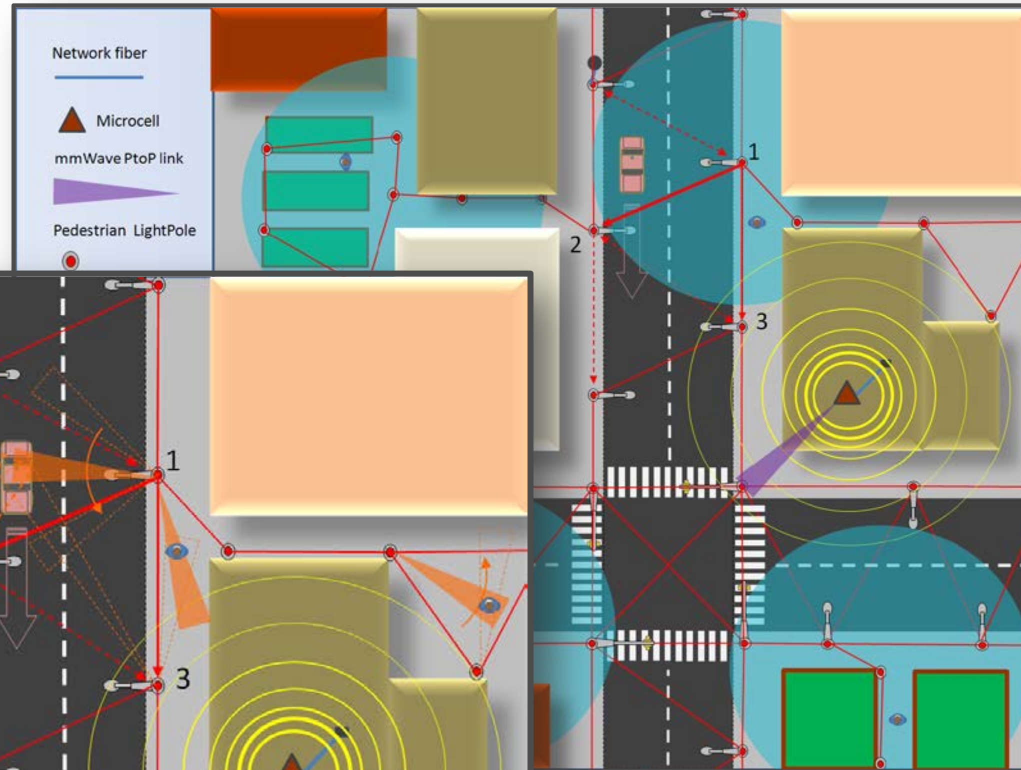
Small Cell – mmWave backhaul

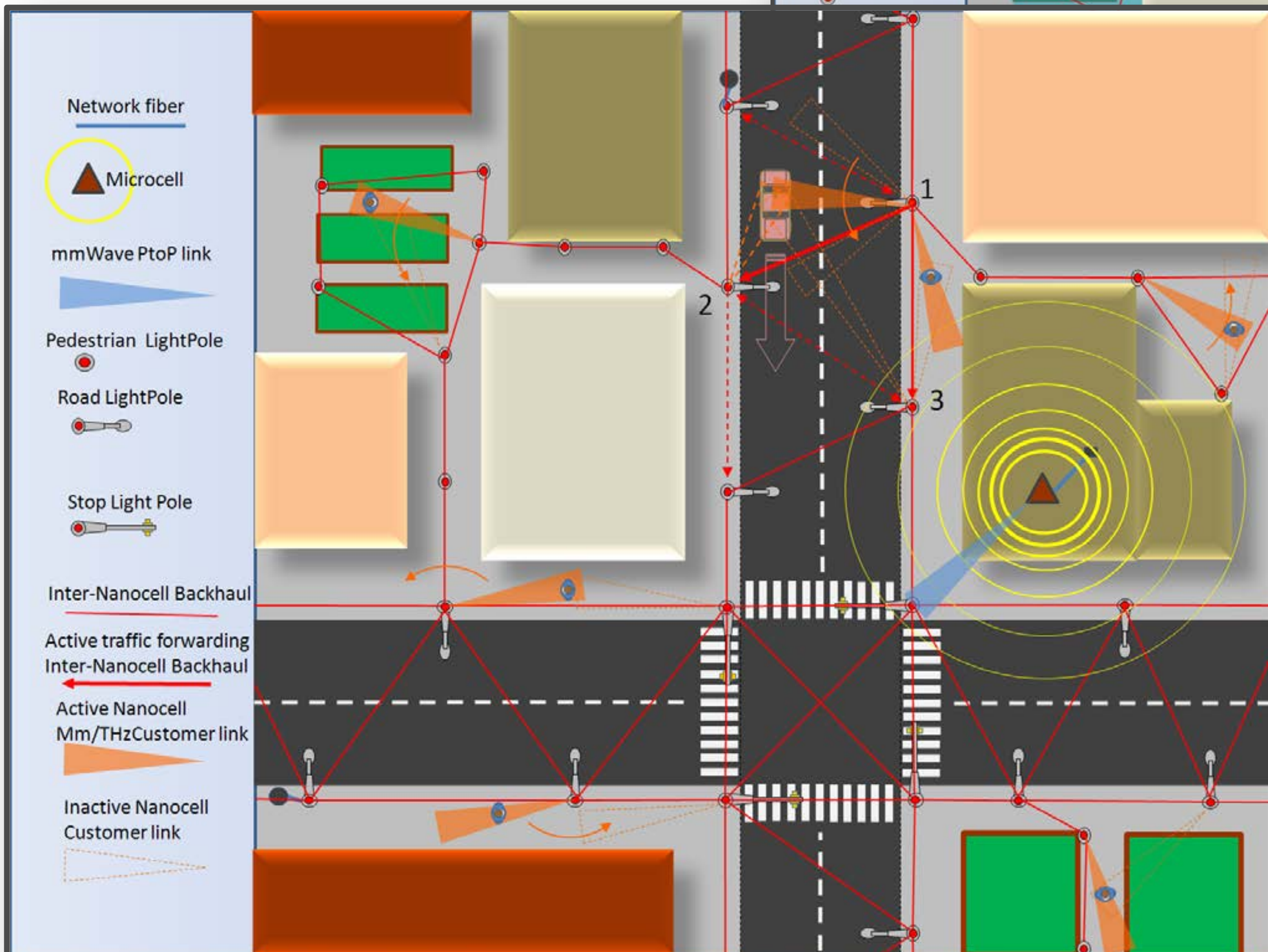


NanoCell mmWave/FSOC backhaul

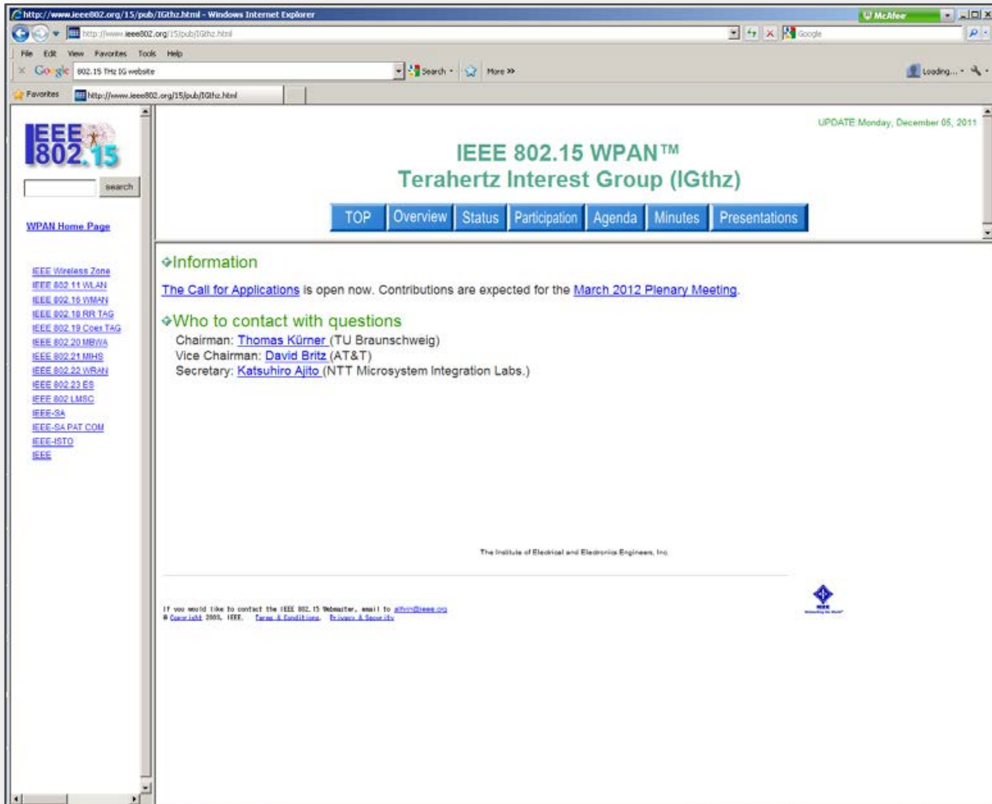


Small Cell Topography





Nanocell Topography



http://www.ieee802.org/15/pub/IGthz.html

Active mmWave and THz Industry and Standards Organizations

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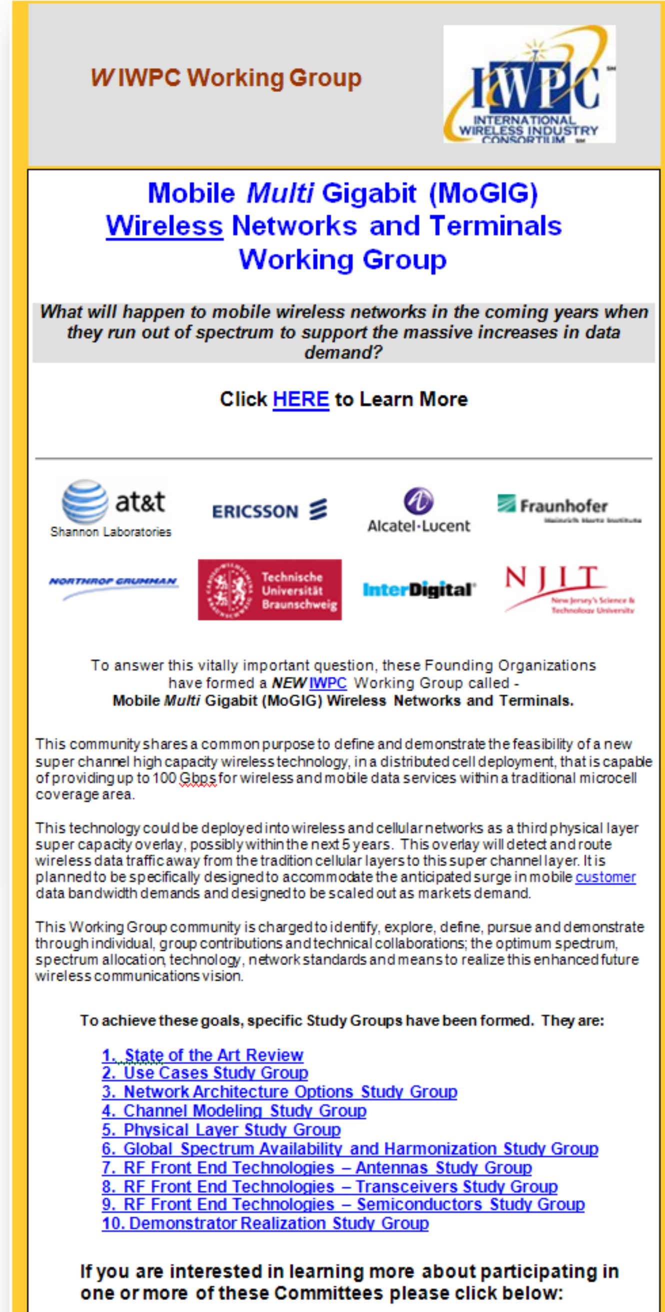

2010 THz Astronomy presentation to 802.15 THz IG

Sharing between radio astronomy and active services at THz frequencies

Andrew W. CLEGG, PhD
U.S. National Science Foundation
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IEEE 802.15 THz Interest Group
Dallas TX, November 8, 2010

2011THz Remote Sensing presentation to 802.15 THz IG

Applications and Requirements for THz Environmental Remote Sensing

Prof. Albin J. GASIEWSKI
University of Colorado at Boulder
and
IEEE-GRSS Frequency Allocations in Remote Sensing (FARS) Technical Group
asiewski@colorado.edu

802.15 THz Interest Group
ta, GA, November 9, 2011

Will THz Communication Interfere with Passive Remote Sensing?

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IEEE TRANSACTIONS ON TERAHERTZ SCIENCE AND TECHNOLOGY 1

Interference Investigations of Active Communications and Passive Earth Exploration Services in the THz Frequency Range

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***Abstract*—At Terahertz frequencies, passive space borne Earth exploration services may be interfered by upcoming active communication applications. Aiming for coexistent use of the THz band by both active and passive applications, this paper identifies critical scenarios where interference can possibly occur. Atmospheric attenuation simulations are used along with appropriate propagation models to account for correct scenario-specific wave propagation conditions. Furthermore, distance-dependent measurements of the path loss are taken at 300 GHz.**

The atmospheric attenuation and propagation models are then employed in order to simulate possible interference powers for the individual reference scenarios under worst case-conditions. Based on existing data for the maximum allowed interference, guidelines for appropriate system specifications of active THz hardware (*e.g.* transmit power constraints) are developed and achievable system performances are evaluated. Countermeasures against potential interference are discussed. Thus, any interference can be anticipated and compensated for already in the early design phase of THz communication systems.

***Index Terms*—THz communications, THz data transmission, 300 GHz, path loss measurements, atmospheric attenuation, spaceborne Earth exploration, interference avoidance**

I. Introduction

Currently, the THz frequency range from 300 GHz to 3000 GHz provides huge unregulated bandwidths, which can help satisfy the ever-growing demand for spectrum [1]. Bandwidths exceeding several 10 GHz will foreseeably be required to serve users with data rates up to 100 Gbit/s [2] over the upcoming decade. Sufficient available spectrum cannot be found below 300 GHz to support these data rates. This ...kes the THz frequencies an excellent candidate for ... wireless ultra broadband communication systems. T... feasibility of multi-Gbit/s data transmissions in th... has already been demonstrated ... different gr... overview is given in [3].

Amongst others, the most important end-user applications are shortest-range kiosk download stations for media files, wireless interconnections between PCs and hardware devices like external hard disks, flash drives or displays and the uncompressed streaming of extremely high resolution video content to a TV [1]. Professional applications comprise wireless backbone links, cable-free data transmission within a data center or telemedicine [4], [5]. Moreover, future public ultra fast wireless LANs can be based on THz nanocells.

Various passive services are already in operation in the THz frequency bands. THz frequencies are of interest especially for remote sensing and earth exploration services. These are referred to as radio astronomy services (RAS), Earth exploration-satellite services (EESS) and space research services (SRS). The EESS and SRS perform air and spaceborne measurements of the molecular absorption lines in the THz band for meteorology, climatology and atmospheric chemistry. Relevant frequencies are multiple bands between 275 and 3000 GHz with up to several tens of GHz bandwidth [6]. The RAS rely on the reception of electromagnetic (EM) waves over the entire THz range from 275 to 3000 GHz to study EM radiation from molecular gas clouds, remote stars or galaxies, for example [7]. In contrast to the EESS, R... activities are primarily ground-based.

According to the ITU Radio Regulat... the frequencies from 275 GHz to 3000 G... from specific allocations. Still, th... of passive ser... spectrum u... correspo...

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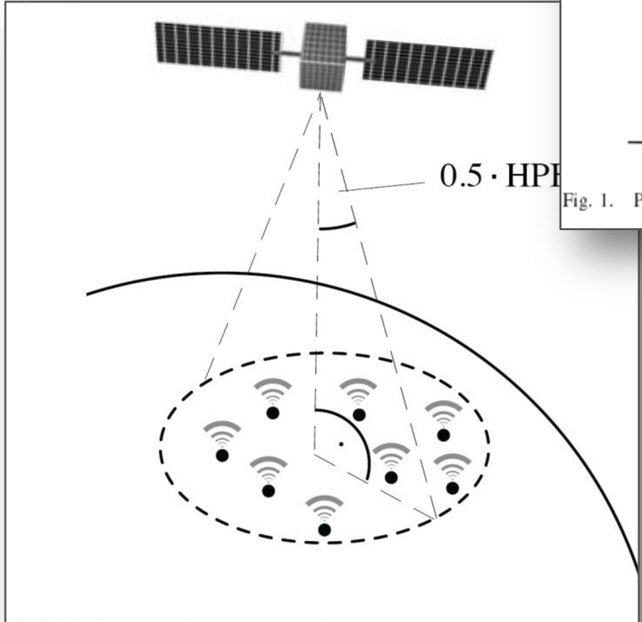
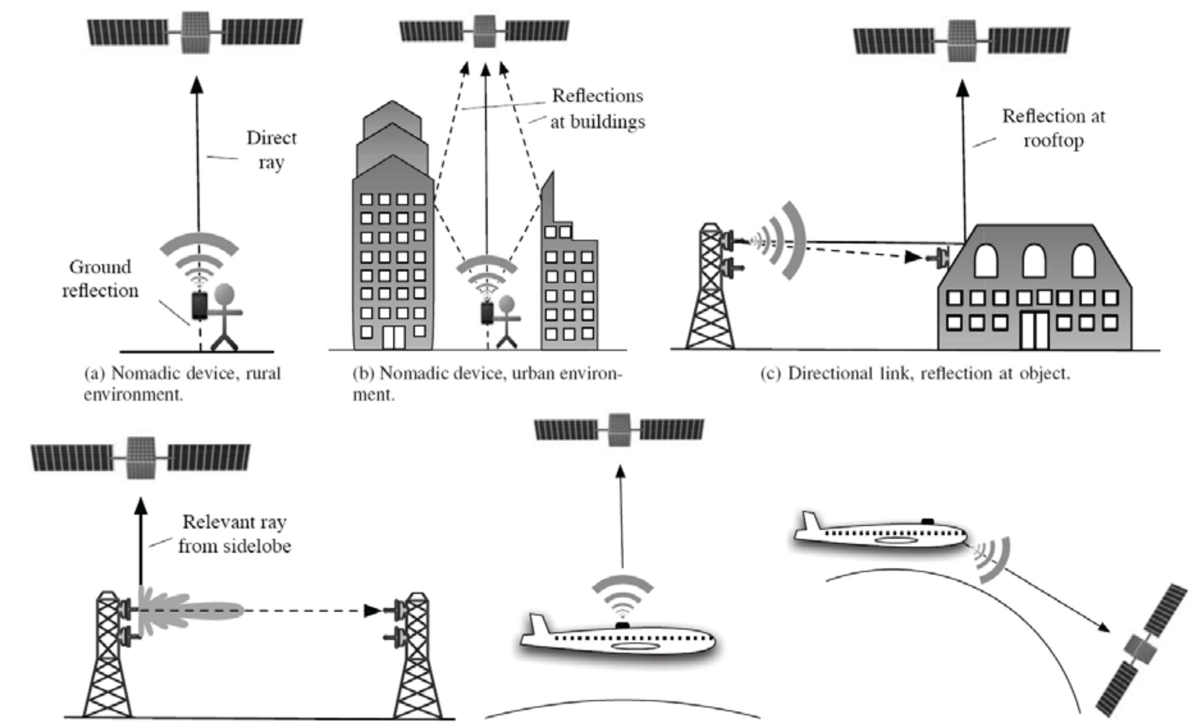


Multiple interference stations.



(a) Nomadic device, rural environment. (b) Nomadic device, urban environment. (c) Directional link, reflection at object. (d) Directional link, sidelobe. (e) Airborne THz system. (f) Limb scanning.

Fig. 1. Possible interference scenarios.

Case scenarios analyzed for Interference

So how do we move forward?

•Evolving wireless communications, societal and customer demand, and expanding technology based wireless services will place unprecedented demand on existing and emerging wireless networks and spectrum utilization.

•**Mobile wireless services has already become a societal structural element! An societal element as important to the very fabric of our society as are electricity, water, homes and highways**

• Wireless mobile communications has also become a societal force that will demand government, sciences and industry work together to solve spectrum sharing concerns.

So how do we move forward?

As a community of regulatory and Industry, standards and radio technology experts need to figure out;

- A common sense and commercially viable approach for cooperative sharing of spectrum for both active and passive services, its' no longer a convenient sound bite,
  it's now a societal imperative!
- How can active services cost effectively protect passive service spectrum and operation?
- How can passive services share spectrum with active services safely and cooperatively?
- Perhaps the emerging intelligent edge network, and small cell/nanocell approach, provides us the best chance to rethink things – especially localized real-time adaptive spectrum usage and management, perhaps even COG based Spectrum AI?
- Perhaps the active and passive services communities can work together, share ideas and collaborate to a solution ? **How? What's the mechanism to provide this venue and ongoing dialogue. How do we enact standards to reflect these solutions?**

One last thought!

The emergence of Small cells and eventually Nanocells , may represent one of the last opportunities ***to get it right!*** By designing in, at the beginning, the critical *active and passive* spectrum coexistence and sharing solutions.

Lets use this new network topography opportunity to work together to find solutions that work for all.

Need More Information?

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