International Network Generations Roadmap (INGR)

An IEEE 5G and Beyond Technology Roadmap

Deployment

1st Edition White Paper

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International Network Generations Roadmap (INGR)

Chapters:

- Applications and Services
- Edge Automation Platform
- Hardware
- Massive MIMO
- Satellite
- Standardization Building Blocks
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ABSTRACT

Wireless technologies have become a fundamental part of our daily life in the 21st century. They connect us to each other and to rich sources of information. They give us the ability to make efficient use of our time, allow us to have remote control over other technologies in our life, and make our lives better in innumerable ways. In order to function, our wireless devices need to connect to cellular sites that provide good coverage both outdoors and indoors. Thus the success of any wireless network is predicated on successful deployment of equipment and systems. As the number of users grows, and the amount of data transferred increases, the laws of physics and information theory requires placement of wireless sites closer to populated areas – creating new challenges for both carriers, site developers, and local governments. Wireless communications facilities cannot be deployed in a vacuum – communication across the product development chain and between private and public entities is critical to enabling practical solutions.

This white paper overviews stakeholder perspectives both public and private, and begins to examine ways to ensure that all stakeholder perspectives are communicated and understood.

Key words:
Deployment, wireless communications facility, site, acquisition, carrier, municipal, local government, product management, marketing requirements, engineering requirements, regulatory, legislative, consensus, 4G, 5G, 6G

DEPLOYMENT WHITE PAPER

1. INTRODUCTION

This white paper gives a broad summary of what one can eventually expect from the continued in-depth roadmap effort from the Deployment Working Group (DWG). It describes a high-level perspective and projection of the topic's technology status, in particular the challenges and gaps that are to be explored and reported on in the 2020 edition of the IEEE International Network Generations Roadmap (INGR). The scope of this white paper is described, stakeholders are summarized, and any expected linkages with the other INGR roadmap working groups are presented.

NOTE: This working group roadmap does not endorse any one solution, company, or research effort.

1.1. CHARTER

The Deployment Working Group (DWG) is a forum for information sharing and discussion among stakeholders in the emerging 5G and beyond economy.

Deployment of wireless communications facilities occurs in a variety of settings; towers and monopoles are sited on private property, public lands, or tribal lands. Heterogeneous Networks (which includes "small cell" sites) are often sited on privately-owned or publicly-owned utility and lighting poles. Applications for these facilities are processed by a variety of government agencies and jurisdictional authorities. The popularity of wireless communications for voice, text messaging, and especially high-speed data has shifted focus for deployments away from high-power and wide area coverage tower sites towards low-power sites on utility and lighting poles—this is called "densification" because it adds capacity and performance to an existing network, focusing resources towards dense clusters of subscribers. Densification means that wireless communication facilities are necessarily sited closer to human populations, which creates unique challenges across the wireless industry.

The goal of the DWG is to help inform the wireless industry about the tactical challenges of deployment in and around public right of way—including private properties adjacent to the public right of way affected by local government zoning/planning, and to highlight the particular needs and perspectives of local governments and municipal agencies where applications for deployment of wireless communications facilities will be reviewed and permitted.

1.2. SCOPE OF WORKING GROUP EFFORT

The DWG will serve as a conduit for municipal stakeholders to communicate their goals and concerns to the wireless industry vendors who are specifying and designing future network products, equipment, and systems. It is hoped that by doing this, the products the industry ultimately produce will have a better chance of making it through local government and municipal agency review, permitting, and appeal processes.

Topics covered by the DWG Roadmap are as follows:

- Local government factors and perspectives affecting deployment
- Regulatory factors affecting deployment

- Public/Community factors and perspectives affecting deployment
- Technology issues affecting deployment

Wireless communication facility deployments occur primarily on three general property categories; privately-owned, publicly-owned, or tribal. Some types of property such as transit stations, water towers, etc. will fall into one of the three categories depending on local variance; e.g., a utility pole might be owned by a government entity, a private utility, a tribal government, or by a joint powers authority.

In most cases the factors and perspectives affecting deployment are common to all wireless technologies and in those cases we make no distinction between 4G, 5G, Wi-Fi, etc. In some cases there are differences between wireless technologies that affect deployment and these are noted as such.

Regulation and/or legislation affect the deployment of wireless technologies. As is often the case, the tensions over local control with state/regional, national, tribal, or international interests are dynamic and evolving. For this roadmap, we note and discuss the effects of regulation and legislation, but the Deployment Roadmap deliberately avoids making policy recommendations.

1.3. Linkages and Stakeholders

The primary stakeholders for the Deployment Roadmap are wireless carriers, local governments and agencies, state/regional governments and agencies, federal governments and agencies, regulatory agencies and commissions, telecommunication site owners, site build contractors, wireless equipment vendors throughout the supply chain, and ultimately residents where the deployment of wireless facilities occurs. Secondary stakeholders include industry organizations, standards bodies, non-profits, and not-for-profits operating in the telecommunications sector.

The work of other INGR groups ultimately influences success or failure of deployment efforts. These groups, and the reasons they are related to deployment, include the following:

- Massive MIMO—The size, weight, and power consumption of Massive MIMO antennae will determine their success in deployment. Poles used for deployment have limited weight-bearing capability. Local governments and agencies often have design standards that require internal wiring—and the conduits that carry wiring must also support lighting, sensors, meters, etc. Municipal aesthetic standards may not allow bulky antenna boxes on poles.
- Edge Computing—Municipal codes and ordinances often assert maximum enclosure sizes for telecommunications equipment. If a given allowed enclosure does not allow for additional equipment, deployment of edge computing cannot occur without changes to the enclosure or modification of the governing codes and ordinances. The size of the leasehold area for the telecommunications equipment can also determine if Edge Computing is viable.
- Optics—The availability of electric power and data backhaul are critical for wireless communication facility deployment. By far, the current preferred backhaul technology is fiber optic cabling.
- Connecting the Unconnected—5G and beyond technologies have the potential to improve coverage in unserved and underserved areas, because it can serve more concurrent user sessions and makes more efficient use of limited spectrum resources. By reducing costs of deployment,

5G and beyond will allow wireless carriers to apply limited capital budgets to more sites, thus extending network coverage to more users.

- Hardware—Densification of wireless networks places site equipment in closer proximity to human populations, which presents challenges for product managers across the hardware development ecosystem. For example, many local governments have noise ordinances for telecommunications and utility equipment, so if a semiconductor intended for use in a 5G radio has low power efficiency, the radio designer may be forced to use an enclosure fan, and the noise from that fan might exceed local noise ordinances. Knowledge of factors affecting deployment informs market and engineering requirements, leads to better product management, and ultimately makes deployment less challenging.
- Security—Today's wireless networks use core servers, but 5G and beyond will allow the siting of edge computing nodes in the field, collocated with wireless radio equipment. Edge computing thus potentially creates increased opportunities for physical security attacks. 5G network architects anticipate that large numbers of edge computing nodes will be required, and ever increasing numbers of small cells will be required as well—especially at the millimeter wave frequencies where path loss limits coverage to under 100 meters. Ongoing pressures to reduce the cost of edge devices and the cost of installing them could also create opportunities for physical security attacks. Mitigating this threat will require network hardening; stronger equipment enclosures, and enhanced security monitoring, creating additional requirements for enclosures—and possibly requiring adjusted municipal codes and ordinances. Mitigating this threat will also require two-way authentication of network devices and edge-computing devices, in addition to the now-standard authentication of subscriber devices. (In other words, just as subscriber devices must prove their authenticity to network devices, network devices must also prove their authenticity to subscriber devices if communications are to be trusted, reliable, and private.)
- Testbeds—Many local governments, eager to reap the political benefits of being seen as an early adopter of 5G and beyond technology, will want to be designated as testbeds.

The INGR DWG anticipates extensive dialog and interaction with other industry groups and standards bodies, as well as organizations that serve the interests of local/regional/state governments. These include the following:

- Standards Bodies
  - American National Standards Institute (ANSI)
  - Telecommunications Industry Association (TIA)
- Industry Groups
  - Cellular Telephony Industry Association (CTIA)
  - GSM Association (GSMA)
  - Small Cell Forum (SCF)
  - Wireless Industry Association (WIA)
- Government Organizations
  - National League of Cities (NLoC)
  - State-based government groups; League of California Cities, etc.

In the experience of the DWG co-chairs, education of local government and agency leaders is critical to successful deployment of wireless communications facilities. Local governments and agencies are often very skilled at managing the traditional roles of government, but they lack experience and expertise in telecommunications—especially small cell 4G and 5G. Budgets constraints and competition for talent limit their ability to resolve this issue via hiring.

2. CURRENT STATE

The first three generations (1G/2G/3G) of cellular technologies were deployed on towers and monopoles away from population centers, in a similar fashion to (and often collocated with) public safety and commercial two-way radio, paging systems, and early mobile telephone service/improved mobile telephone service (MTS/IMTS) systems. While conflicts with residents and governments/agencies over these sites were not unknown, in general they were located away from population centers and as such any conflicts were usually over view line aesthetics, potential fire risks, and possible impacts to nature preservation areas. 4G technologies originally followed this deployment model, but user demand grew exponentially after introduction of the smartphone—creating negative effects on network performance.

To improve 4G network performance, and to make more efficient use of limited spectrum allocations, the wireless industry turned to densification via Heterogeneous Networks (HetNets), combining tower sites with Distributed Antenna Systems (DAS) and small cell facilities—low power sites that put signals near users and population centers. Unfortunately, this densification created several issues:

- Siting near population centers led to resident fears about health effects from electromagnetic radiation, property valuations, and aesthetics.
- The number of applications for wireless facilities in the public rights of way went up dramatically, adding workload to municipal staff.
- The question of cost for both application processing and lease rate for siting on public infrastructure is unresolved. Municipal governments assert rights to control on behalf of residents and variable local conditions, whereas regulatory bodies assert harmonization of costs and rates in the interest of providing coverage to the general population.
- The issue of aesthetics (both visual and auditory) becomes important during the application process, especially during public review and planning/zoning hearings.
- The IEEE, ICNIRP, FCC, EPA, ETSI, United Nations ITU and WHO (see Section 7 acronym table for clarification), numerous researchers, and numerous industry groups have expended much effort over the past five decades to research health effects from electromagnetic fields (EMFs) and to establish science-based standards for safe EMF exposure. The FCC in particular has asserted authority over RF exposure safety standards, and that authority preempts state and local governments from denying deployment of wireless communication facilities based on concerns about the safety of RF exposure. And yet, some local governments and some so-called public interest groups continue to question the safety of even low levels of RF exposure.

Right now, a web search for “5G safety” will return several pages of opposition, ranging from somewhat reasonable perspectives urging caution to unsupportable pseudoscience and even outright conspiracy theories. It is not an exaggeration to say that groups opposed to deployment of wireless technologies—especially those in opposition to cellular deployments—are winning the public debate solely by being

vastly more prolific in publishing material in support of their position and driving search engines towards their perspective.

3. FUTURE STATE

Given that 5G networks in millimeter wave bands will require 10 times more small cell sites than 4G networks, we should expect that the issues outlined in **Current State** (Section 2, above) will only be exacerbated—indeed we are already seeing growing resistance from community groups over wireless facility deployments, based largely on concerns amplified by urban legends and pseudoscientific fears about 5G health concerns.

Expertise from a wide variety of resources must be brought to bear on the deployment challenge. For example, engagement with the medical research community to review studies and publish expert opinions will help bring sanity to the current state of evidentiary self-selection. Despite more than 50 years of existing research, some politicians have called on the wireless industry to fund additional research into electromagnetic health effects. We believe any studies funded by industry will be tainted by perceived (or real) bias, and thus we believe that funding for health research must come from government itself in order to remain above reproach.

The potential value of the IEEE as a voice of reason in the deployment debate cannot be understated. IEEE C95.1 forms the basis for current regulatory guidelines including the aforementioned U.S. Federal Communications Commission safety guidelines.[1] The IEEE, while known to the general public primarily via association with Wi-Fi and the 802.11 family of standards, is large enough and independent enough to drive fact-based public discussion and education around the complex challenge of deployment.

Key to the success of this effort is continued partnership with industry groups, standards bodies, and government organizations. Dialog between the wireless industry, carriers, site owners, local governments, agencies, and residents is a proven formula for success, but it does not happen organically.

The question of local control versus federal control must be resolved. Courts and legislative bodies will need to nullify, modify, or uphold regulatory rulings—whatever happens, the uncertainty is damaging to planning and requires resolution.

The deployment challenge will require creative thinking, partnership, and cooperation among all stakeholders. For example; to alleviate the lack of telecommunications expertise in local governments, the industry should consider a “talent partnership” model that would fund employees of carriers, wireless site owner/operator companies, and technology vendors to do a one-year working sabbatical with a local government or municipal agency. The government or agency would benefit from the added no-cost headcount, the industry employee would pass along knowledge in the process, and the employee would develop a first-hand understanding of municipal government operations and processes.

In a perfect world, presuming alignment between most or all stakeholders, we envision:

- Within three years:
    - IEEE has successfully engaged in publication of public-facing fact-based articles and materials addressing the deployment challenge.

[1] *https://standards.ieee.org/standard/C95_1-2019.html*

  - After a review of the 2019 update to IEEE C95.1, the Federal Communications Commission reaffirmed their electromagnetic safety guidance in OET-65 Bulletin,[2] and closed their 2013 proceeding initiated to update electromagnetic safety standards. Likewise, the International Commission on Non-Ionizing Radiation Protection updated their guidance in light of the IEEE C95.1-2019 update. After some initial concern from opposition groups, these actions are now accepted by stakeholders.
  - Stakeholder meetings between the wireless industry, governments, and standards bodies have developed an initial framework for dialog and interaction.
  - Wireless equipment vendors have adjusted their product roadmaps and offerings to meet the major concerns against deployment expressed by local governments, municipal agencies, and residents.
  - Local governments and municipal agencies are beginning, with the help of industry-funded talent partnerships, to build up staff with telecommunications experience.
  - Courts and legislative bodies have resolved the federal mandate versus local control debate.
- Within five years:
  - IEEE is considered a leading "go-to" source for the press and media reporting on the subject of wireless technologies and deployment challenges.
  - Wireless equipment vendors are continuing to produce products that meet or exceed requirements outlined by government and public stakeholders for deployment.
  - Local governments and municipal agencies are mostly staffed and trained to accept and review applications for 5G wireless communication facilities.
- Within ten years:
  - The success of the 5G deployment over the preceding decade has laid the foundation for future success as 6G and other technologies near standardization and begin to displace 5G and earlier technologies.

4. Requirements and Knowledge Gaps

Deliberate effort coordinated by third parties (chambers of commerce, economic development non-profits, regional think tanks, etc.) must be initiated, led, and sustained over several years to build momentum, understanding, and trust among stakeholders. Thus, the solution to successful deployment of 5G and beyond networks will require a multi-pronged approach—education of leaders in local government and public agencies, education of the public about electromagnetic radiation safety and socio-economic impacts, and a shift in strategy during industry product design and development to better understand the 5G and beyond deployment challenge.

As of 2019, very few local governments (absent some major cities) have staff with the experience and technical knowledge to properly review wireless facility applications. This creates conflict and tension between local governments and applicants. Responsibility for telecommunications is assigned to planning departments when the proposed site is on private property, and assigned to public works when the proposed site is on municipal property in the public right of way. In either case, there is a need for

[2] *https://www.fcc.gov/general/oet-bulletins-line*

education of municipal employees. A certification program would also be highly valuable, as it would help local governments seeking to hire staff for telecommunications know that applicants are educated on relevant topics.

Likewise, many vendors of wireless site equipment have little to no experience working in local governments. This creates a problem where equipment available for deployment does not satisfy local aesthetic codes and guidelines, forcing the carrier or site operator to push for waivers or relaxations of codes and guidelines.

Given that local governments need to build up telecommunications expertise, and equipment vendors need to understand municipal aesthetics and perspectives, talent partnership programs that would place engineers and technicians on sabbaticals working in local government could be helpful to alleviate talent shortages and improve mutual understanding.

5. ROADMAP TIMELINE CHART

Table 1 Working Group Needs, Challenges, and Enablers and Potential Solutions

Name	*Current State (2020)*	*3 years (2023)*	*5 years (2025)*	*Future State 10-years (2030)*
IEEE public-facing documents	Does not exist	Publication occurring	Publication ongoing	Publication ongoing
Challenge(s) for Need 1	Resources (writers, editors, PR managers)	---	---	---
Possible Solution for Challenge	IEEE commitment to funding. Funding can *not* come from industry.	---	---	---
Regulatory agency adoption of IEEE C95.1 and ICNIRP standards.	Possibly occurring, but uncertain.	Adoption.	---	---
Challenge(s) for Need 2	FCC may not prioritize this action in light of other pressing topics.	---	---	---
Possible Solution for Challenge	Lobbying by IEEE.	---	---	---
Stakeholder meetings between industry, local governments, and standards bodies.	Occurring in small pockets across the country.	Meetings occurring	Meetings ongoing	Meetings ongoing
Challenge(s) for Need 3	Resources (facilitators, convening organizations, financial support for venue and misc.) Commitment to process by participants does not yet exist.	---	---	---
Possible Solution for Challenge	Encouragement by IEEE to follow existing models. Publication of articles outlining existing processes that work.	---	---	---
Local governments staffed to handle telecommunications applications.	Lack of telecom experience in local government staff.	Some local governments are trained to handle application. Engineer/technician sabbatical program augments training.	Local governments are trained to handle applications. Engineer/technician sabbatical program continues.	Local governments are trained to handle applications.

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7. ACRONYMS/ABBREVIATIONS

Term	Definition
1G-4G	First Generation to Fourth Generation
3GPP	Third Generation Partnership Project
5G	Fifth Generation
ACK/NAK	Acknowledgment/negative acknowledgment
AI	Artificial intelligence
ANSI	American National Standards Institute
API	Application programming interface
B2B	Business to business
B2C	Business to consumer
BS	Base station
BSS	Business support system
C/U	Control plane / User plane
CAPEX	Capital expenditure
CDMA	Code division multiple access
CN	Core network
COTS	Commercial off-the-shelf
CP	Control plane
CTIA	Cellular Telephony Industry Association
D2D	Device to device
DAS	Distributed Antenna Systems
DevOps	Development and information technology operations
DFT-s-OFDM	Discrete Fourier transform spread orthogonal frequency division multiplexing
DL	Downlink
DWG	Deployment Working Group
EAP	Edge automation platform
eMBB	Enhanced mobile broadband
eNB	Evolved node B
EPA,	Environmental Protection Agency
EPC	Evolved packet core
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
FDD	Frequency-division duplex
FDMA	Frequency division multiple access
GHz	Gigahertz
GSMA	GSM (Groupe Speciale Mobile) Association
HetNets	Heterogenous Networks
HIR	Heterogeneous Integration Roadmap
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IMS	IP multi-media subsystem
IMTS	Improved MTS
IoT	Internet of things
IP	Internet protocol
IRDS	International Roadmap for Devices and Systems
ISG	Industrial specification group

ISP	Internet service provider
ITS	Intelligent transport system
ITU	International Telecommunication Union
ITU-T	ITU Telecommunication Standardization Sector
KPI	Key performance indicator
LAA	Licensed assisted access
LDPC	Low-density parity-check
LTE	Long-term evolution
M2M	Machine to machine
MAC	Medium access control
MANO	Management and orchestration
MEC	Multi-access edge cloud
MIMO	Multiple input, multiple output
ML	Machine learning
mMTC	Massive machine-type communication
mmWave	Millimeter wave
MR	Merged reality
MTS	Mobile Telephone Service
MVNO	Mobile virtual network operators
NaaS	Network as a service
NF	Network function
NFV	Network function virtualization
NGC	Next generation core
NGMN	Next generation mobile networks
NLoC	National League of Cities
NOMA	Non-orthogonal multiple accesses
NR	New radio
NS	Network slicing
NSA	Non-standalone
OEC	Open edge computing
OFDM	Orthogonal frequency-division multiplexing
OMEC	Open mobile edge cloud
OPEX	Operational expenditure
OPNFV	Open platform network virtualization
OSS	Operational support system
OTT	Over the top
PGW	Packet gateway
PHY	Physical layer
PoC	Proof of concept
QoS	Quality of service
RAN	Radio access network
RE	Range extension
RSRP	Reference signal received power
SCF	Small Cell Forum
SDN	Software defined network
SDO	Standards developing organization or standards development organization
SIM	Subscriber identification module
SLA	Service level agreements
SON	Self-optimizing network
TDD	Time-division duplex

TDMA	Time division multiple access
TIA	Telecommunications Industry Association
TSDSI	Telecommunications Standards Development Society India
TTI	Transmission time interval
UAV	Autonomous aerial vehicles
UE	User equipment
UL	Uplink
UP	User plane
URLLC	Ultra-low reliability low latency connection
V2I	Vehicle to infrastructure
V2V	Vehicle to vehicle
vEPC	Virtual evolved packet core
VNF	Virtual network function
WG	Working group
WHO	World Health Organization
WIA	Wireless Industry Association
WRC	World Radiocommunication Conferences

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Generally speaking, most of the world prohibits agreements and certain other activities that unreasonably restrain trade. The IEEE Future Networks Initiative follows the Anti-trust and Competition policy set forth by the IEEE-SA. That policy can be found at https://standards.ieee.org/develop/policies/antitrust.pdf.

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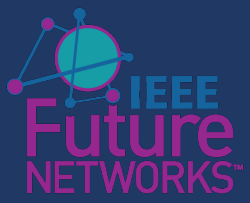

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