

Terahertz Wireless Spectrum: Economic Benefits, challenges and Future Trends

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Overview

- Introduction
- Research questions
- Terahertz (THz) technology
- Characteristics of THz spectrum
- Current challenges
- Research requirement and future directions
- Regulatory and Economic impacts
- Conclusion

Introduction

- Importance of higher frequency spectrum for 6G and beyond communication systems
 - 5G (mmWave) frequency bands becoming increasingly crowded to cater ever growing data demands
 - Limited by narrower bandwidth
 - Support broad range of 5G applications but inadequate for next generation such Internet of nano things (IoNT)
- Role of Terahertz (THz) frequencies (300 GHz to 3 THz)
 - Provide frequency spectrum enabling higher data rates
 - Integrate new technologies and business solutions
- Technological and regulatory barriers
 - **Limited Source Power:** Terahertz sources often exhibit low power output, making it challenging to generate strong and coherent THz waves
 - **Propagation Loss:** Although THz waves can penetrate various materials, they still face significant propagation loss, especially in moist environments.
 - **Spectrum Allocation:** There is a lack of established international standards and management practices for THz frequencies
 - **Licensing:** Securing licenses for using certain THz frequencies can be a convoluted process, subject to varying national and regional guidelines.

Research questions

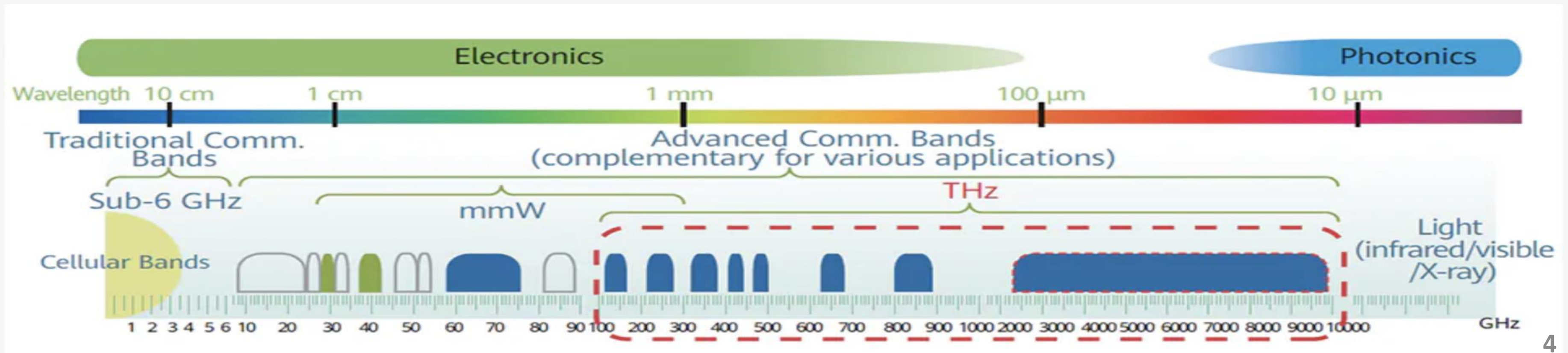
- ❖ RQ 1: What are the primary challenges and opportunities perceived by industry professionals regarding the adoption and integration of THz technology in wireless communication systems?
- ❖ RQ 2: How do regulatory policies and spectrum management practices influence the development and commercialization of THz technologies across different regions?

THz Spectrum & Key Characteristics

- Terahertz (THz) frequencies, ranging from 100 GHz to 3 THz, play a crucial role in the future of wireless communication, particularly for 6G and beyond networks

- THz frequencies offer vast, uninterrupted spectrum blocks, addressing the scarcity of usable spectrum below 100 GHz

- This expansion is critical for meeting the growing demands of future wireless networks.
- By utilizing THz frequencies, it is possible to alleviate congestion in lower frequency bands, improving overall network efficiency and reliability
- THz spectrum represents a new frontier for spectrum management and innovative utilization methods



Challenges & Research needs

Regulatory Uncertainties

- As THz technology is relatively new for communication purposes, there is a need for:
 - Establishing new regulatory frameworks
 - Developing safety standards specific to THz frequencies
 - Balancing innovation with health concerns

Limited Range:

- Due to high attenuation and low penetration power, THz communication is currently more suitable for indoor environments with limited mobility requirements.

High Signal Attenuation

- THz signals experience substantial path loss, which is notably higher than in lower frequency bands. This attenuation is influenced by factors such as:
 - Humidity
 - Distance between transmitter and receiver,
 - Atmospheric conditions

Spectrum management

- Experimentation with new technologies and regulatory approaches, potentially leading to more efficient and effective spectrum use
- THz technology can significantly enhance the capacity and efficiency of wireless networks by providing high-bandwidth

Industrial view on THz adaption

Challenges in Adoption:

- High signal attenuation limits range, posing infrastructure challenges for wide-scale deployment.
- Lack of mature technology, including efficient transceiver design and scalable materials.
- Need for global harmonization of spectrum allocation and standards.

Demand for High-Speed Connectivity:

- Industries anticipate utilizing THz frequencies for ultra-fast data transfer, enabling innovations like real-time digital twins and autonomous operations.
- THz offers capabilities to bridge the gap between fiber-optic speeds and wireless mobility.

Timeline for Implementation:

- Gradual adoption starting with niche applications (e.g., high-speed backhaul, sensing technologies).
- Widespread use expected in the 2030s, following advancements in 6G networks.

Spectrum Management and Regulatory Policies

- The International Telecommunication Union (ITU) has made significant strides in allocating frequency bands for THz research, such as the 300 GHz to 1 THz range
- (ITU) has indeed recognized the potential of frequencies above 275 GHz for active communication services

- Regulatory policies determine how the electromagnetic spectrum is divided among various services and applications
 - THz technologies, which span from 0.1 THz to 10 THz, the allocation of specific frequency bands is critical.
- International bodies like the ITU and CEPT (Conference of Postal and Telecommunications Administrations) play a pivotal role in establishing the technical framework for THz spectrum utilization

- Countries with well-defined licensing procedures, such as the U.S. and the European Union, have seen more rapid development and commercialization of THz technologies compared to regions with less clarity
- Earlier proposals had suggested allocating an additional 102.2 GHz for licensed use and 15.2 GHz for unlicensed use above 100 GHz. However, due to substantial pushback from various industry stakeholders, the FCC has currently deferred these licensing proposals
- The ongoing debate and regulatory developments highlight the complexities and challenges involved in managing high-frequency spectrum

Outcomes

- Elaborate on the potential challenges while utilizing THz Spectrum
- THz answer addressing capacity constrains of lower frequency bands
- THz technology requires research and development to establish stable communication
- FCC implemented streamlined rules managed by a third party for straight forward license approval for new links
- The diverse nature of potential THz users, which includes satellite communications, mobile networks, medical imaging, and scientific research, necessitates a flexible approach to standardization
- Difficult for single body
- single standards body may struggle to meet the specific needs of all stakeholders, potentially hindering innovation and limiting the full potential of the THz spectrum
- collaborative and inclusive framework for standardization required to meet specific needs of all stakeholders
- Framework should involve multiple standards organisations, industry leaders, academic researchers and cell phone operators

Outcomes (cont'd)

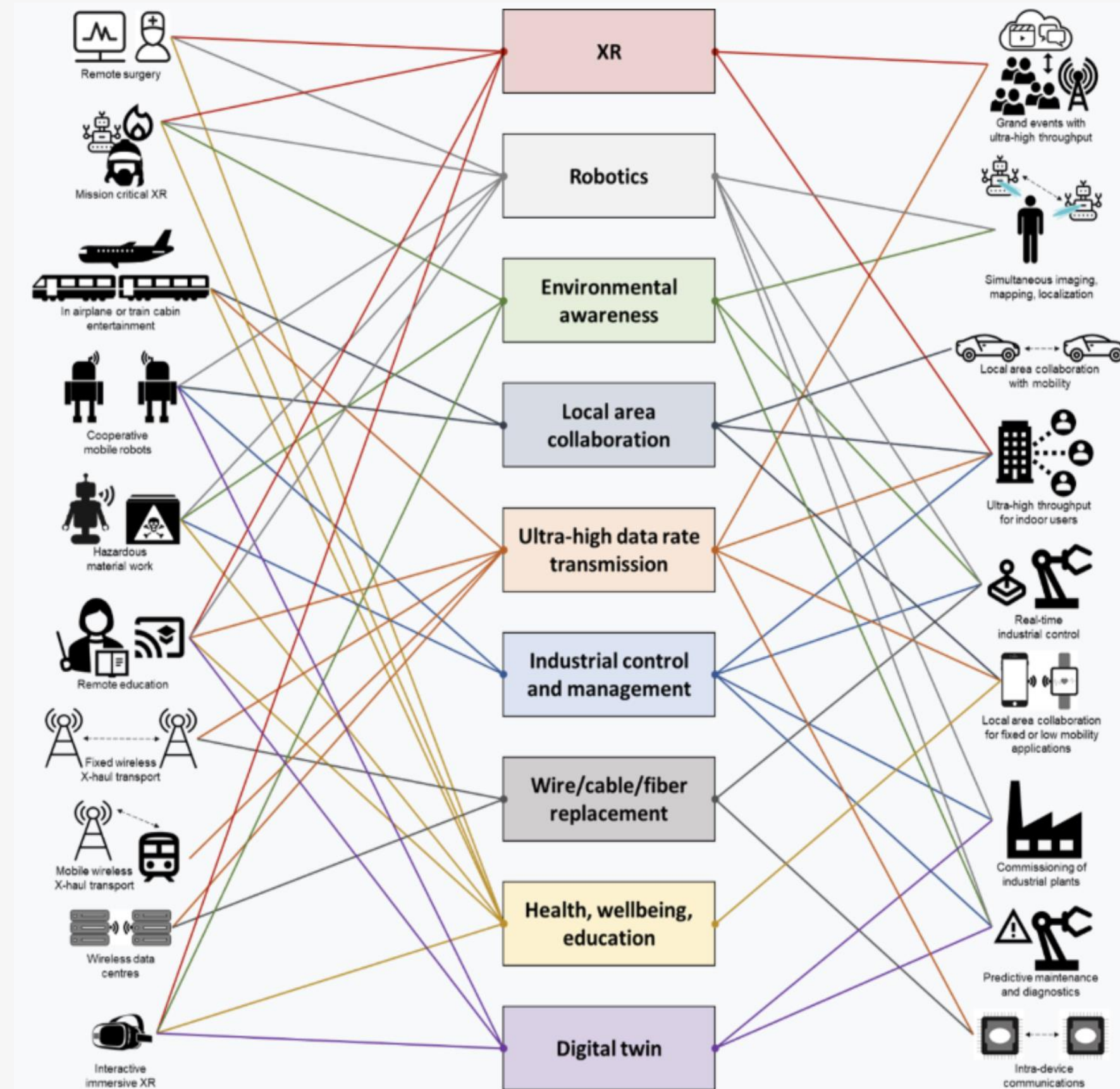
- What can be done:
 - Investing in research and development to explore standards implications
 - Pilot-testing of these standards to provide effectiveness of these standards
- International collaboration is also essential to harmonize the spectrum policies
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Spectrum Future Management

- **Goal:** Develop a forward-looking vision for THz spectrum management
- **Encourage Collaboration:** Stimulate international collaboration among industry stakeholders and regulatory bodies
- **Engagement with Emerging Users:**
 - Fixed links
 - Short-range radar systems
 - Speculative applications for 6G technologies
- **Focus Areas:**
 - Understand emerging user requirements
 - Integrate with existing spectrum users
 - Address challenges posed by current users
 - Explore solutions to accommodate future entrants into the THz spectrum
- **Enhancing Collaboration:**
 - Foster global coordination among diverse spectrum uses
 - Optimize THz spectrum utilization globally
- **Building on R&D Capabilities:**
 - Empower universities and research laboratories to leverage their strengths
 - Address technological and capability gaps crucial for the future
 - Encourage active contributions from US and European sectors for global 6G development
- **Spectrum Allocation for 6G:**
 - Identify and allocate spectrum promptly for R&D and innovation
 - Ensure regional alignment and harmonization to prevent spectrum fragmentation
 - Support international economies of scale
- **Future Focus Areas for 6G:**
 - Emphasize local-area and indoor applications.
 - Incorporate THz spectrum with applications like sensing.
 - Consider applications operating independently of broader networks.

Conclusion

- **Potential of THz Spectrum:**
 - Accommodates diverse applications:
 - High-speed data transfers for close-proximity devices
 - Networking paradigms at the nanoscale
 - Set to transform wireless communication and drive innovation
- **Challenges and Opportunities:**
 - Significant technical challenges remain
 - Holistic approach needed to unlock THz spectrum potential
- **Key Elements for Success:**
 - Development of aligned standards
 - Creation of innovative business models
 - Implementation of supportive regulatory frameworks
- **Goal:** Convergence of these elements for successful commercialization within the broader wireless ecosystem



Thank you!