Future Broadband Technologies

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Agenda

- Edge computing
- Quantum computing
- Fiber optic innovations
- Combining satellite and mobile wireless service
- 6G wireless
- Wi-Fi advancements
- Li-Fi developments

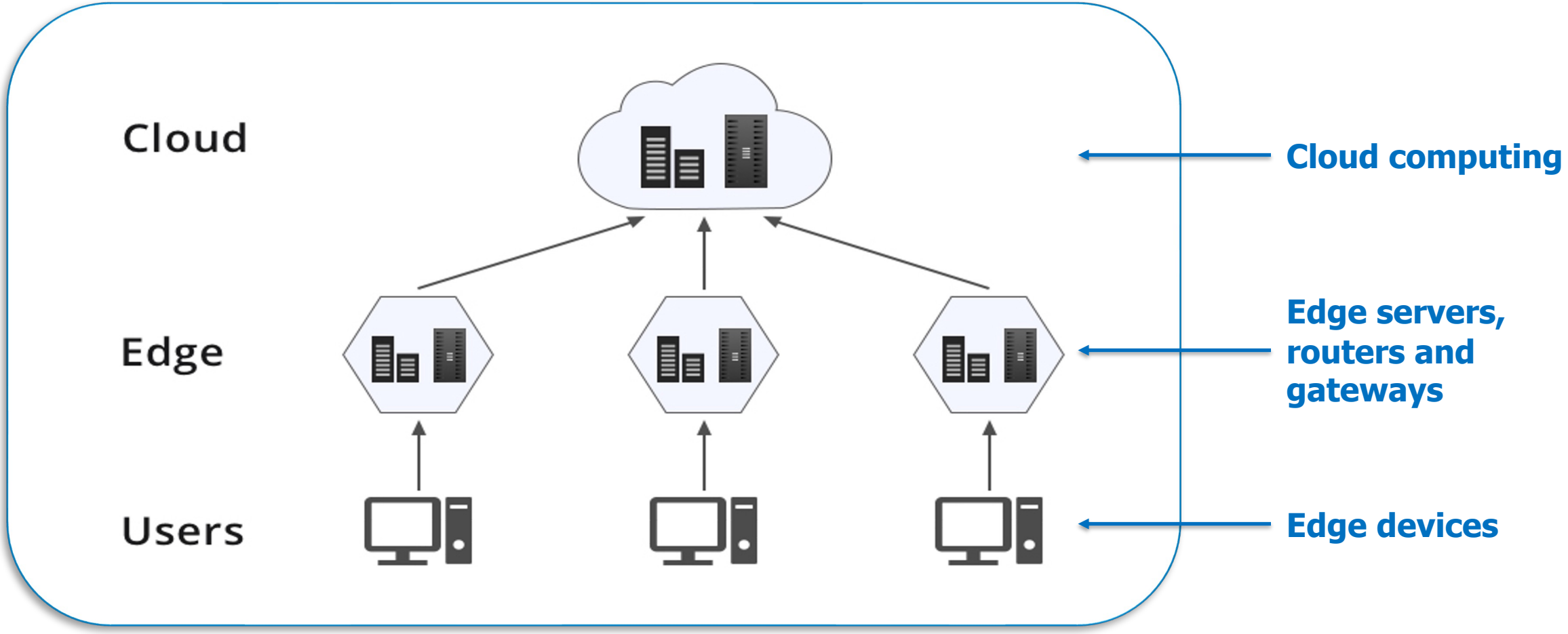
Edge computing

Source: Image generated by ChatGPT

Edge computing

- Decentralization is the key
- Biggest advantage – reduced latency
- What about cloud computing's pros and cons?
- Can edge computing and cloud computing work together?
- Gartner research states as of 2025, 75% of enterprise-generated data is created and processed outside traditional centralized data centers or cloud environments
- Global edge computing market projected to reach $45.5 billion by 2028 with a current compound annual growth rate of 25%

Edge computing
Components



Source: FS

Edge computing
Common applications

- **IoT devices** – processing data generated by IoT devices
- **Smart manufacturing** – predictive maintenance and quality control
- **Smart cities** – traffic management and public safety
- **Health care** – remote patient monitoring and telemedicine
- **Autonomous vehicles** – real-time navigation and object detection
- **Content delivery** – caching content (e.g., music and video)
- **Gaming, virtual reality and augmented reality** – reduce latency
- **Artificial intelligence at the edge** – allows for real-time data analysis

Edge computing
Effect on rural LECs

- Pros
  - Improved service delivery
  - Efficient network management
  - Data privacy and security
  - Offline operation
  - Cost efficiency
- Cons
  - Complexities
  - Investment challenges

Edge computing
Opportunities

- Identify use cases – providers should identify specific use cases where edge computing can provide the most value
  - Including reducing latency for real-time applications, optimizing bandwidth usage, supporting IoT deployments or offering value-added services like edge analytics
- Content delivery networks – telcos can deploy edge servers at their network edges to cache popular content locally
- Network security – edge computing enables telcos to implement security mechanisms to detect and mitigate threats closer to the source
- Develop edge applications – telecommunication providers should develop or partner with third-party developers to create edge applications

Quantum computing and communications

Source: Image generated by ChatGPT

Quantum computing

- Quantum computing – a new way of processing information using the principles of quantum mechanics, which is the science that explains how atoms behave
- Unlike regular computers that use bits (which can be either 0 or 1), quantum computers use qubits, which can be both 0 and 1 at the same time due to a property called superposition

- Using a phenomenon know as quantum entanglement, qubits can also be linked together, even across distances, allowing them to solve certain problems much faster than regular computers
- Quantum computing offers unbreakable encryption, faster drug discovery, advanced AI, revolutionizing cybersecurity and medicine

Quantum communications
Potential benefits

- Quantum Communications – a method of sending information using qubits, instead of classical bits
  - Faster, lower latency and more efficient use of bandwidth
  - Offers unbreakable security and tamper detection, ensuring any interception or interference with the communication is immediately detectable
- Quantum teleportation – a process by which the quantum state of a particle is transferred from one location to another without moving the particle itself using quantum entanglement and classical communications
  - Quantum communications could, in theory, enable faster communication by bypassing the physical limitations of signal transmission, but current quantum systems are not yet capable of matching the data throughput of fiber optics

Quantum communications
Anticipated timeframe

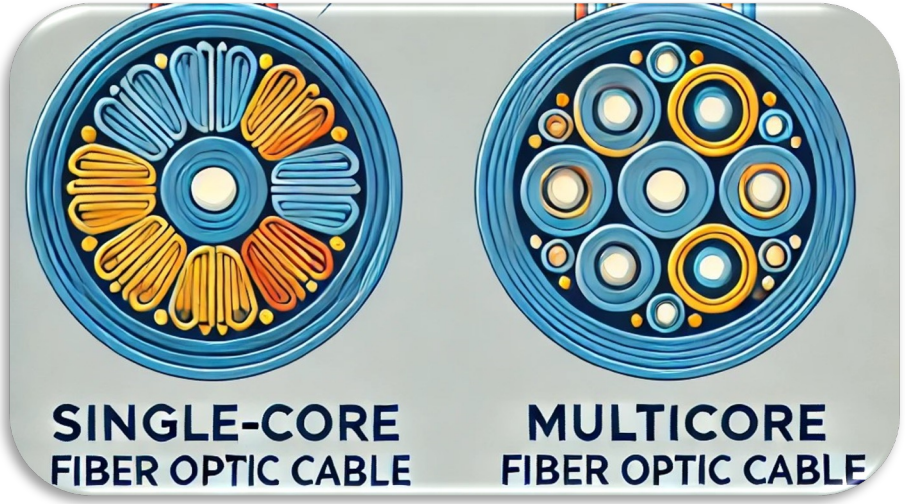
- Quantum teleportation has been successfully demonstrated over distances of hundreds of kilometers using optical fibers and satellite links
- Efforts are underway to build quantum communication networks
  - Prototype quantum networks, such as between government and research institutions for secure communication, are expected in the next five to 10 years
  - Regional quantum networks for data transfer over metropolitan or regional scales in next 10-15 years
  - Global quantum networks, for example the quantum internet, expected in 15+ years

Fiber optic innovations

Source: Image generated by ChatGPT

Fiber optic innovations
Multicore fiber and space division multiplexing

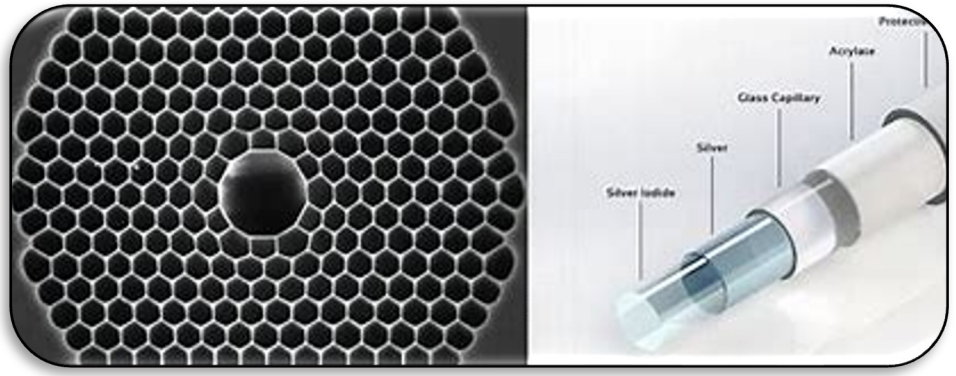
- Multicore fiber – incorporates multiple cores within a single fiber strand, allowing simultaneous data transmission over parallel cores
  - Significantly increases data capacity without requiring more physical fibers
  - A single MCF can replace multiple single-core fibers, reducing space requirements in cables and conduits
  - Ideal for dense urban environments, data centers and submarine cable systems
  - Requires advanced space division multiplexing equipment to handle data from multiple cores
  - Widespread commercial adoption is expected in the next five to 10 years



Source: IPT Fiber

Fiber optic innovations
Hollow-core fiber

- Hollow-core fiber – Evolving fiber technology that uses a hollow core instead of solid glass to transmit light, significantly reducing latency and signal loss
  - Ideal for ultralow latency applications and long-distance communications
  - More challenging to manufacture and currently more expensive
  - While the use of hollow-core fiber is not yet widespread, it is gaining traction in specific high-performance applications, such as aerospace, defense and research labs



Source: FCST.com

Fiber optic innovations
Artificial intelligence integration

- The integration of artificial intelligence with fiber optic transmissions is an emerging trend that aims to optimize the performance, efficiency and management of optical networks
  - AI algorithms can analyze network traffic patterns and predict periods of high demand
  - Dynamic bandwidth allocation – AI can adjust bandwidth allocation in real time based on traffic conditions
  - Self-healing networks – AI enables the development of self-healing networks, where the system can autonomously detect and recover from faults without human intervention

Combining satellite and mobile wireless service

Source: Image generated by ChatGPT

Combining satellite and mobile wireless service

- Rural and remote connectivity – provides internet access in remote locations, helping to bridge the digital divide
- Emergency services – ensures communication during disasters when terrestrial networks may fail or when out of range of a cell tower
- Internet of Things – supports IoT devices in hard-to-reach areas, such as smart agriculture or maritime applications
- Military and defense – offers resilient, secure communication for troops and vehicles in remote locations
- Seamless roaming – allows mobile users to maintain connectivity while transitioning between terrestrial and satellite networks during travel

Combining satellite and mobile wireless service

- For years, satellite communication has remained a standalone technology, independent of mobile networking
- In the near future, LEO broadband satellites will integrate with terrestrial mobile wireless networks to manage connectivity to cars, vessels, airplanes and mobile devices – iPhone 14 Pro and later have emergency satellite texting
- Satellites will soon be able to provide backhaul services for terrestrial wireless networks

Combining satellite and mobile wireless service

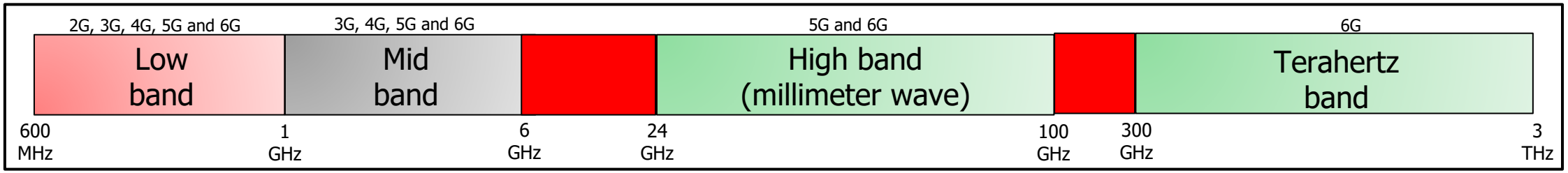
- In October 2021, Verizon said they would work to combine its 5G wireless network with Amazon's Kuiper and AT&T agreed to work with OneWeb
- SpaceX began testing its Starlink satellite-to-cell service with T-Mobile in 2023, vowing to end mobile dead zones. Beta testing was open to anyone through July 2025
- AST SpaceMobile is contracting with most cellular phone makers and service providers (e.g., Nokia, Google, AT&T, Verizon, Samsung, Vodafone) to make a space-based cellular broadband network. First test mobile video call with standard smartphone was made in January 2025

6G wireless

Source: Image generated by ChatGPT

6G wireless

- 6G, referring to sixth generation, is the next evolution of fixed and mobile wireless communication technology, anticipated to succeed 5G
- Anticipated speeds exceeding 1 terabit per second
- Extremely low latency
- Massive connectivity
- Will utilize terahertz frequency bands, providing huge data carrying capacity



6G wireless
Challenges

- THz band may only be suitable for very short distances
  - Signal attenuation in the THz band is extremely high
  - Will likely require densely deployed small cells – MIMO
- Will likely require very high energy usage to boost signal strength
- Hardware limitations – designing efficient transceivers, antennas and amplifiers capable of operating at THz frequencies is a significant challenge
  - New, more complex handsets will be needed to use 6G

6G wireless
When?

- The United States, China, European Union, South Korea and Japan all have government-led programs working on the development of 6G
- Technology giants like Samsung, Nokia and Apple are all researching aspects of 6G deployment
- Anticipated timeframes
  - Research and standardization efforts continue during 2025-2027
  - Early deployment and commercial rollout during 2028-2030
  - Widespread commercial deployment begins 2030
  - Large scale deployment in a global quantum internet begins 2040

Wi-Fi advancements

Source: Image generated by ChatGPT

Wi-Fi advancements

- Ultra-fast internet speeds – ideal for ultra-high-definition streaming, augmented reality/virtual reality and downloading massive files in seconds
- Improved network capacity – handles significantly more devices simultaneously, making it perfect for smart homes, offices and IoT-heavy environments
- Lower latency – essential for gaming, AR/VR and other latency-sensitive applications
- Better performance in crowded areas – uses advanced frequency management and wider channels to maintain high performance even in congested networks

Wi-Fi advancements
Recent versions

Wi-Fi version comparison

Wi-Fi generation	Release year	Max speed	Frequency bands
Wi-Fi 4 (802.11n)	2009	0.6 Gbps	2.4/5 GHz
Wi-Fi 5 (802.11ac)	2014	3.5 Gbps	5 GHz
Wi-Fi 6/6E (802.11ax)	2019/2020	9.6 Gbps	2.4/5/6 GHz

Source of data: ChatGPT

Wi-Fi advancements
Version 7

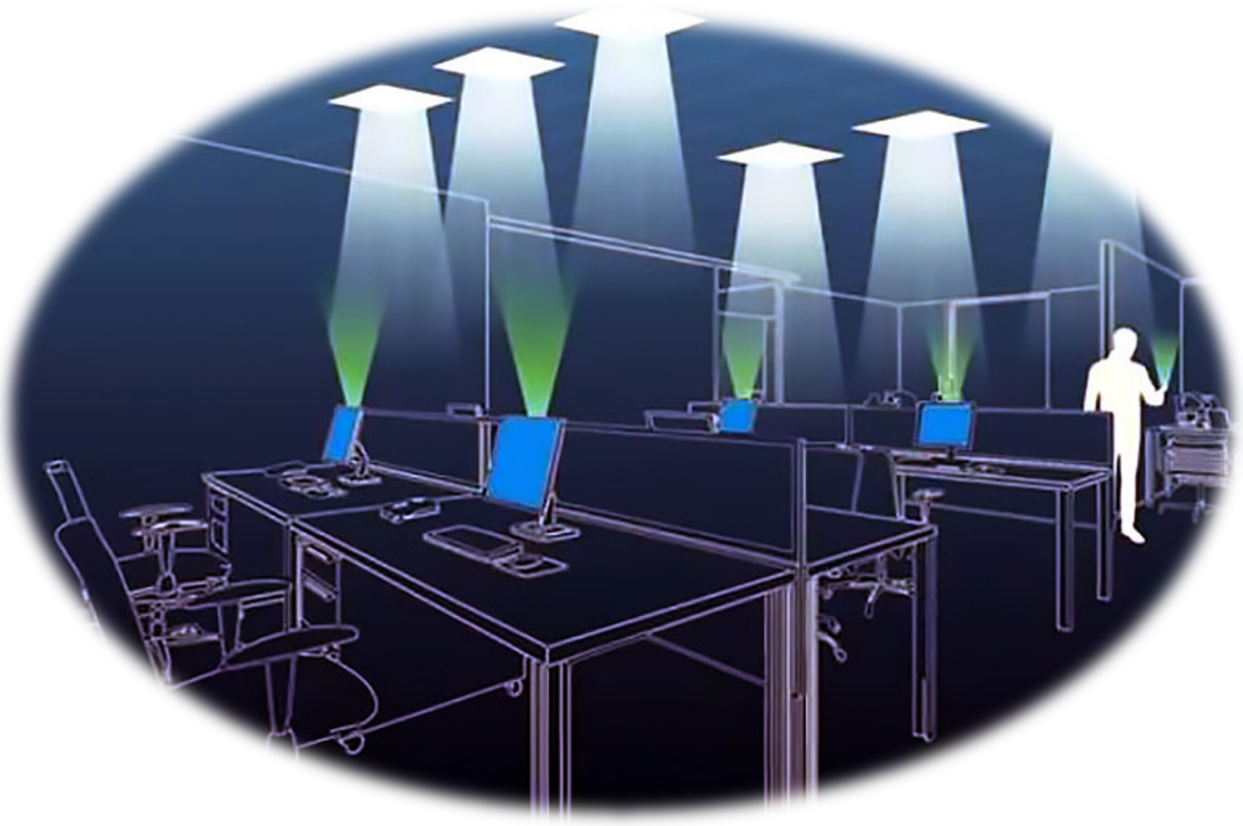
- Introduced in 2024, Wi-Fi 7 (802.11be) can achieve speeds of 46 Gbps with lower latency
- Multilink operation – Wi-Fi 7 devices can connect simultaneously across multiple frequency bands (2.4 GHz, 5 GHz and 6 GHz) to improve performance, reduce latency and enhance reliability
  - Dynamically adjusts to the least congested band, ensuring stable connections even in crowded environments
- Supports more simultaneous users by optimizing spatial streams and beamforming

Li-Fi developments

Source: Image generated by ChatGPT

Li-Fi developments

Source: Next Li-Fi



Source: CodeCondo

Li-Fi developments

- Light fidelity – a wireless communication technology that uses light waves, typically from LEDs to transmit data
- Li-Fi operates similarly to Wi-Fi but with light instead of radio waves
- Li-Fi enables fast data transfer by using visible light communication, providing significantly higher speeds compared to traditional Wi-Fi
- Li-Fi can be used to deliver broadband internet access by expanding wireless communication into various areas where Wi-Fi might struggle
- Compared to Wi-Fi, Li-Fi is faster, more secure and creates no interference
- Implementing Li-Fi necessitates the installation of compatible LED lighting systems equipped with data transmission capabilities

Summary

- The future of computing and technology show major signs of continuing to grow and advance
- The next few years should prove to be interesting, with several of these technologies in the testing stages now
- Opportunities are available for rural telecommunications providers
- Like everything, there are some pros and cons, but knowledge is the key to seeing how this works with your networks

Any questions?

Acronyms

AI	Artificial Intelligence
FCC	Federal Communications Commission
Gbps	Gigabits per Second
GHz	Gigahertz
IoT	Internet of Things
LEC	Local Exchange Carrier
LED	Light-emitting Diode
LEO	Low Earth Orbit
Li-Fi	Light Fidelity
MCF	Multicore fiber
MIMO	Multiple Input Multiple Output
NECA	National Exchange Carrier Association
Wi-Fi	Wireless Fidelity