

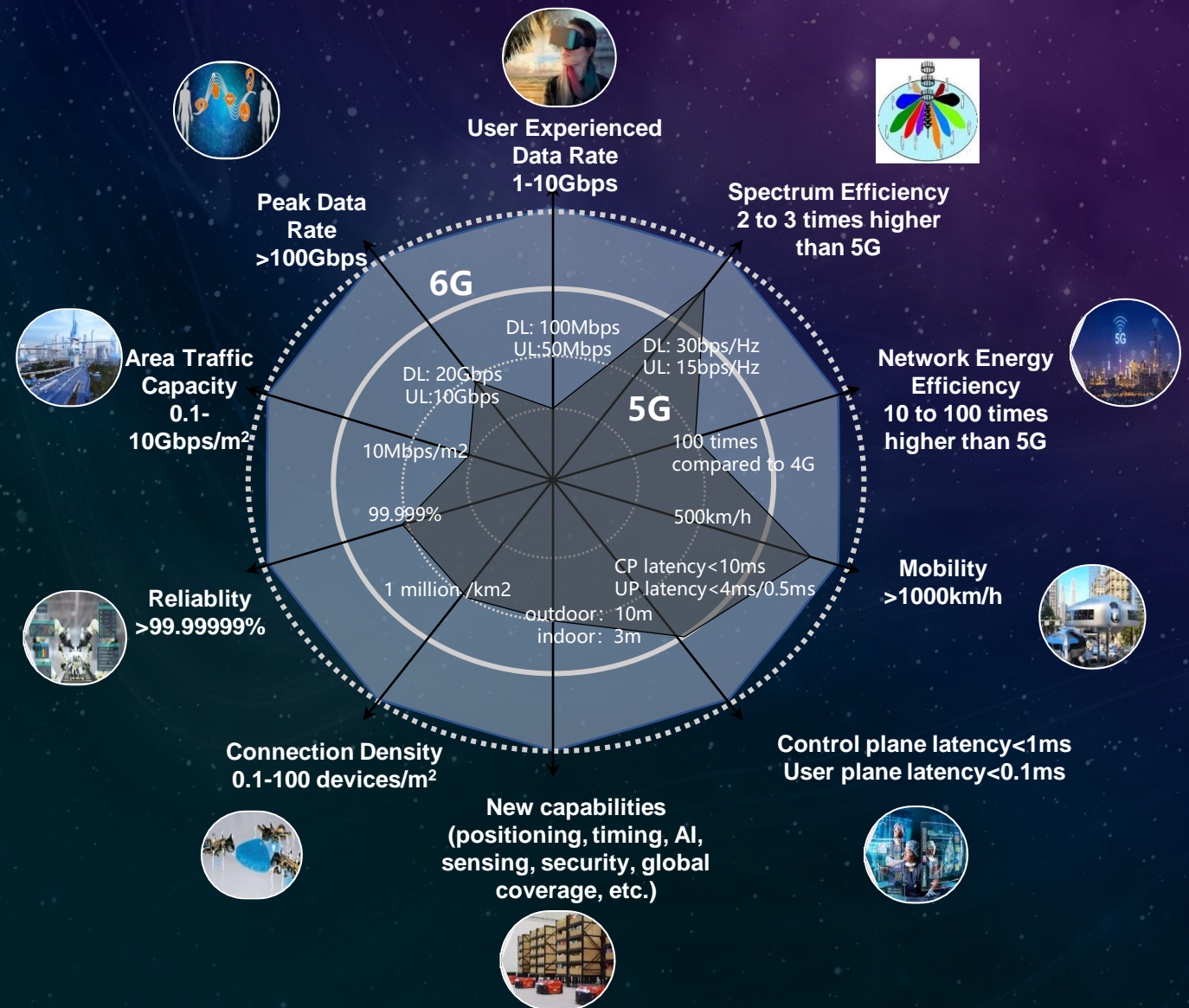
VLC in 6G Mobile Communication

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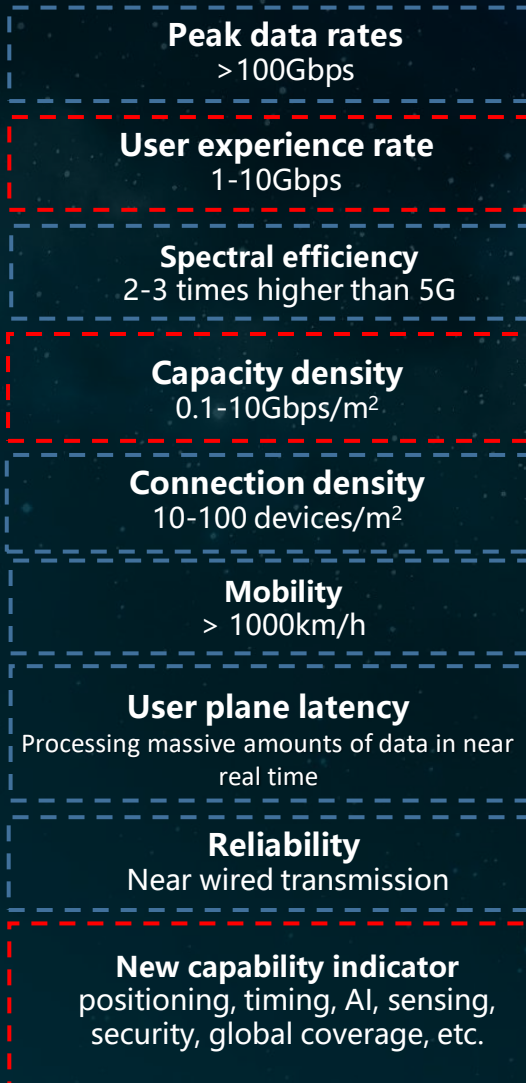
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6G Capability

- 6G will increase the requirements of key performance dramatically on the basis of existing 5G capability
- 6G will provide more comprehensive performance than 5G, such as high-precision positioning, AI, security, computing, sensing, etc.



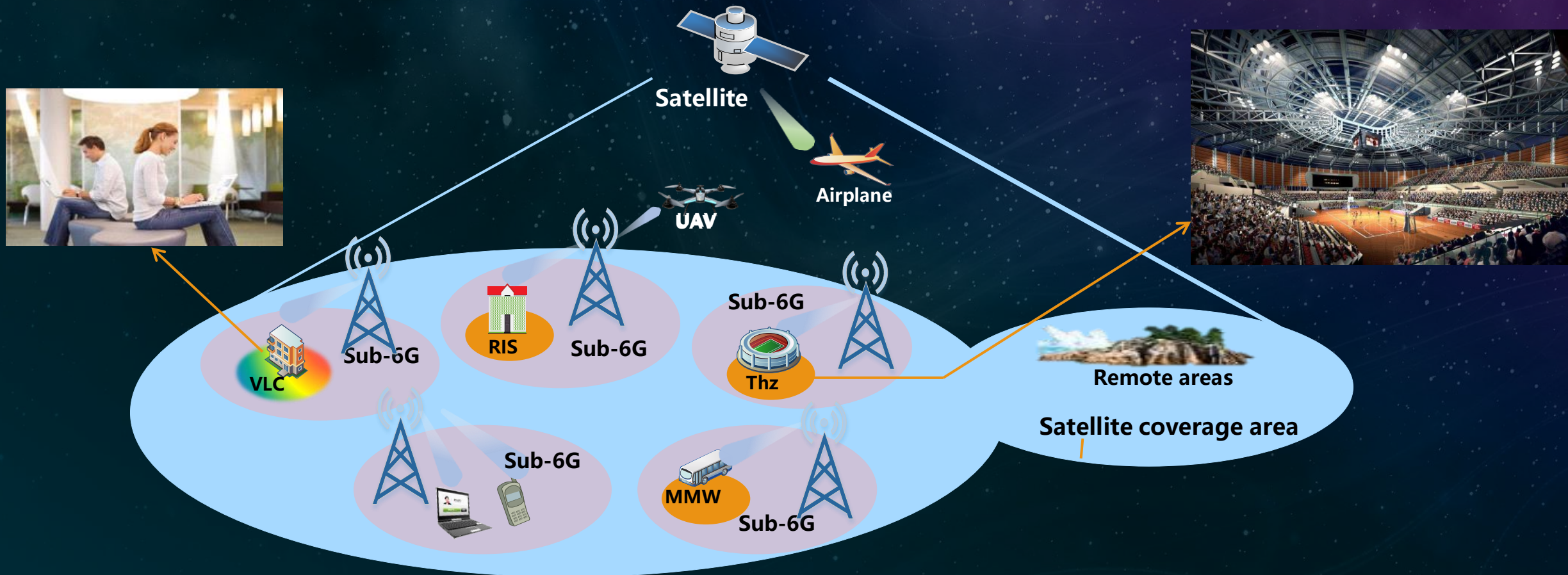
6G Candidate Technologies



6G Multi-dimension Integrated Network

Coverage: extended from wide area to global three-dimensional area, including micro area

Frequency: Multiple frequency bands are integrated used, low-band provides basic coverage, while high-band such as MMW, THz and VLC are enabled on demand for high performance service.



Mobile communication scenarios of VLC

- Indoor mobile high-capacity scenarios⁽¹⁾
 - Requirement: Tens of Gbps peak data rate, 100Mbps/m²
- Vertical industry scenarios⁽²⁾
 - Requirement: ultra-high reliability and low latency, high-accurate positioning
- Traffic scenarios⁽³⁾
 - Requirement: ultra-high reliability and low latency, high-accurate positioning
- Harsh electromagnetic scenarios⁽⁴⁾
 - Requirement: high data rate, ultra-high reliability and low latency, high-accurate positioning
- Challenges:
 - Mobility management, spectral efficiency, light beam tracking, light noise and interference elimination, collaborative resource management, optical power control.



(1)



(2)



(3)



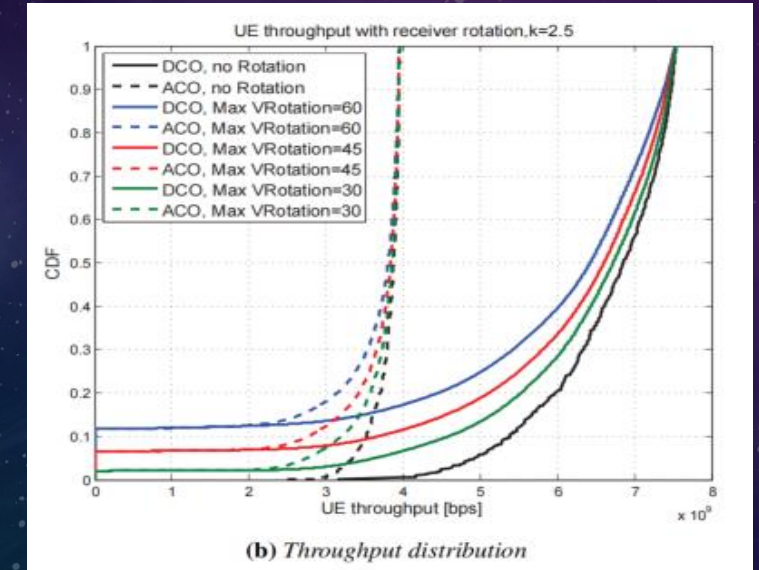
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Requirements of VLC in 6G Mobile communication

- Requirement of data rate, targeting 300Mbps/m² capacity density
 - Ultra dense deployment: 2x2x3 m³ per VLC AP
 - coverage angle requirement: $2 \cdot \text{atan}(1/3) = 37^\circ$
 - average data rate per AP: 1.2Gbps
 - peak data rate per AP: 4.8Gbps
 - Modulation bandwidth requirement: 5GHz (OOK is assumed)
 - Normal deployment: 4x4x3 m³ per VLC AP
 - coverage angle requirement: $2 \cdot \text{atan}(2/3) = 67^\circ$
 - average data rate per AP: 4.8Gbps
 - peak data rate per AP: 19.2Gbps
 - Modulation bandwidth requirement: 5GHz (O-OFDM+QAM is assumed)
- Requirement of VLC device
 - Modulation bandwidth: 5GHz
 - coverage angle/FOV: 60°
 - coverage area: 4x4x3m³

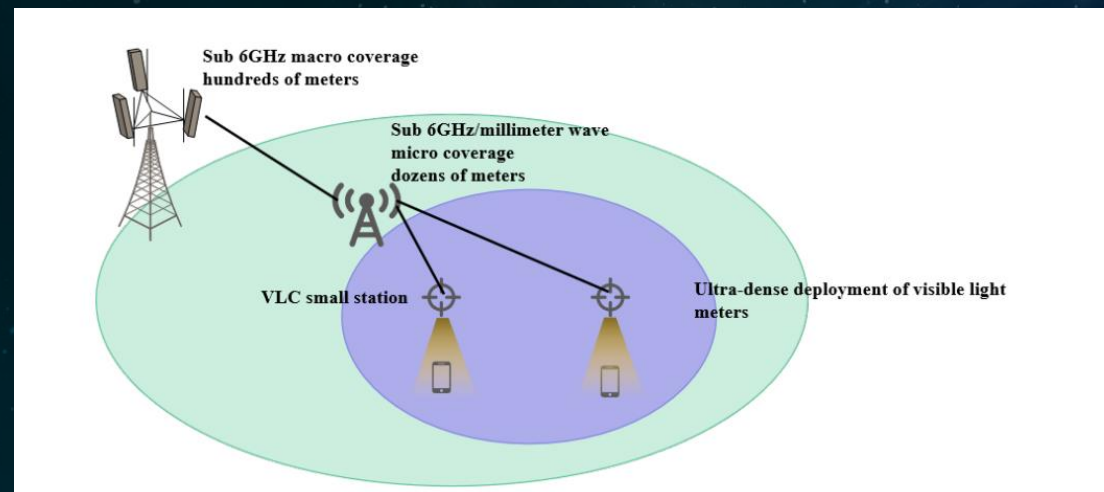
Requirements of VLC in Mobile communication scenarios

- Requirement of networking
 - **Support low-speed mobile scenario**
 - Changes of environment, UE position, receiver direction need to be considered.
 - **Support Interruptionless transmission**
 - According the simulation, around 10% UE cannot receive VLC signal
 - **Support bidirectional transmission**
 - VLC uplink is a bottleneck, considering light pollution
- Radio frequency could be used as supplyment, integrated networking of VLC and RF is necessary.



Integrated Networking of RF and VLC

- Frequency dimension: Through visible light communication and deep fusion transmission of full frequency bands such as frequency bands below 6GHz and millimeter wave, multi-frequency integrated collaborative management and dynamic complementarity can be realized
- Spatial dimension: macro coverage + micro coverage + ultra-dense heterogeneous network is realized to optimize the network service quality and reduce network energy consumption.

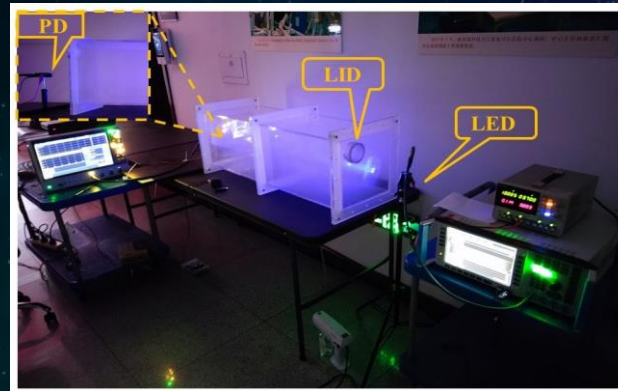
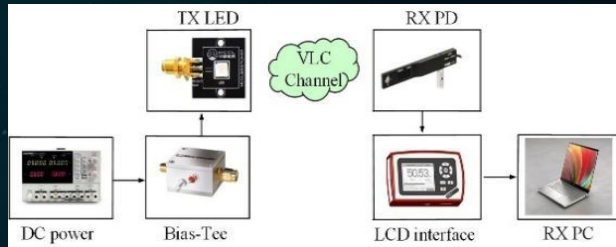


Integrated Networking of RF and VLC

- **Integrated Access of RF and VLC**
 - VLC AP discovery procedure could be assisted by RF AP
 - Random access based on RF uplink is needed.
 - Connect to the RF base station first or the VLC node first.
- **Integrated Cell Selection/Reselection of RF and VLC**
 - VLC AP selection/reselection could be assisted by RF AP
 - Multiple VLC APs selection should be considered in ultra-dense deployment scenario.
- **Integrated Transmission of RF and VLC**
 - HARQ/CSI feedback based on RF uplink.
 - Time alignment among RF APs and VLC APs is needed.
- **Integrated connectivity management of RF and VLC**
 - Targeting zero interrupt delay, fast switching between RF link and VLC link is necessary.
- **Integrated Load/Energy balancing of RF and VLC**
 - VLC service first may help to same network resource and power.
 - Illumination requirement may be additional factor to be considered.
- **Integrated positioning/sensing of RF and VLC**
 - VLC could be used to improve network positioning/sensing capacity.
 - VLC may sense environment to enhance AI-based RF channel measurement.

On-going work on VLC of China Mobile

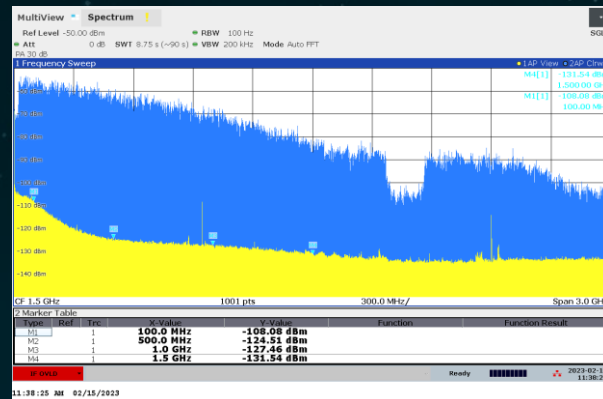
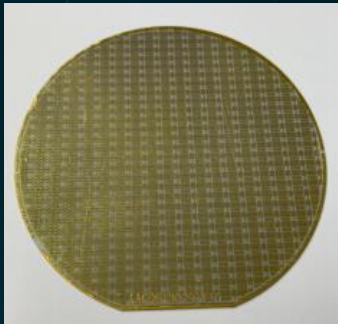
VLC channel measurement & modeling



High data rate VLC link-level demo



High data rate VLC device



VLC network demo



Summary

6G VLC target: support mobile scenario, support ultra-high data rate, support ultra-density deployment with high power efficiency & low cost

Improve performance

01

- To satisfy 6G requirement, supply higher data rate and traffic density
- To be competitive comparing with other potential 6G frequency band

Integrate into mobile wireless networks

02

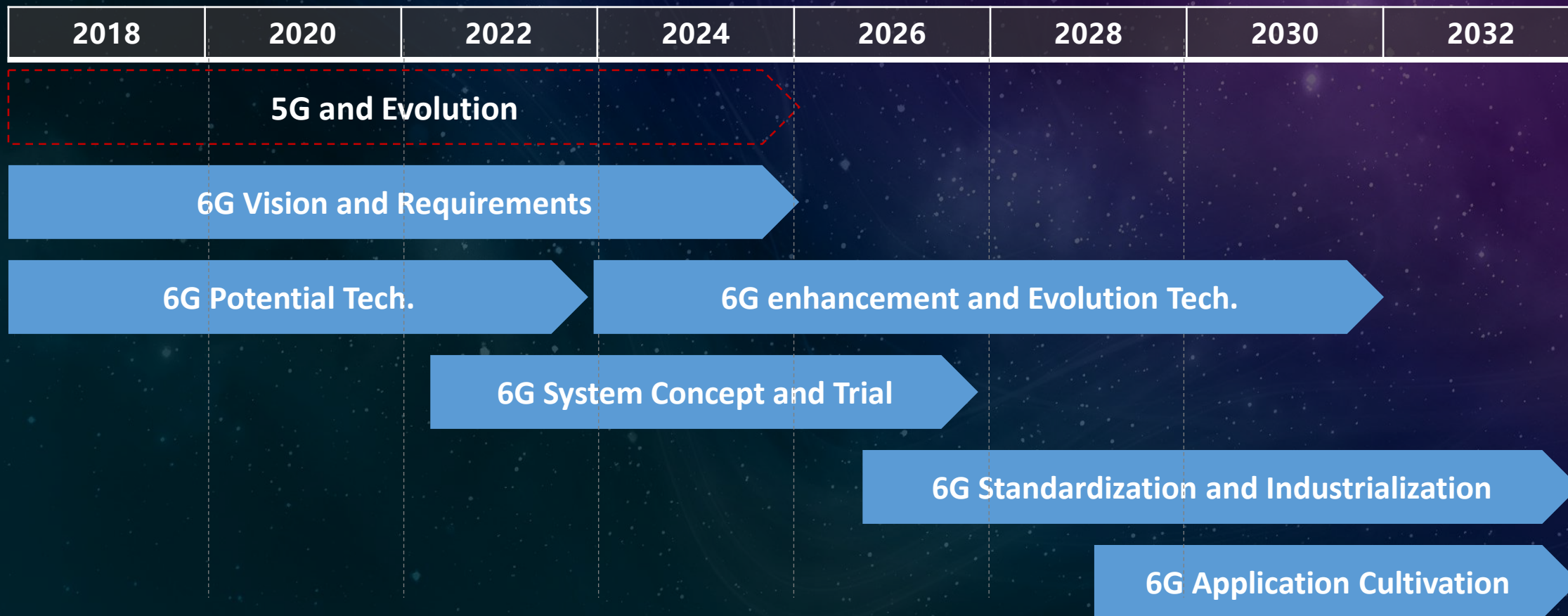
- To supply mobile service
- To be integrated with mobile network and mobile device

Develop industry chain

03

- To develop VLC Tx/Rx device targeting higher bandwidth, higher optical power, low cost, etc.
- To specify VLC device requirement

China Mobile's 6G Plan



6G Phased Plan

- **Phase I (2018-2025)** : 6G Vision and Requirements, Potential Key Tech., System Concept and Trial
- **Phase II (2025-2030)** : 6G Specification, Industrialization, Precommercial Trial and APP/Service Cultivation



Thanks!