

Update on standards for mobile optics and opportunities with HCF



<https://mopa-alliance.org>

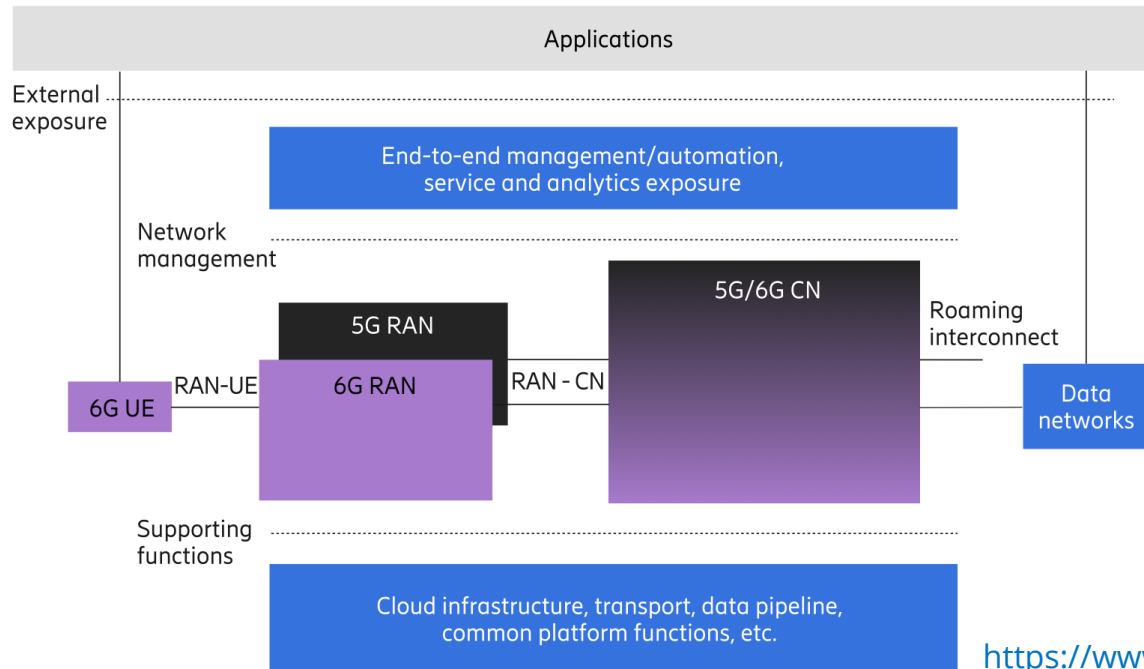
Kenneth Jackson (Sumitomo Electric)
September 28, 2025

What is 6G ?

Advanced use cases

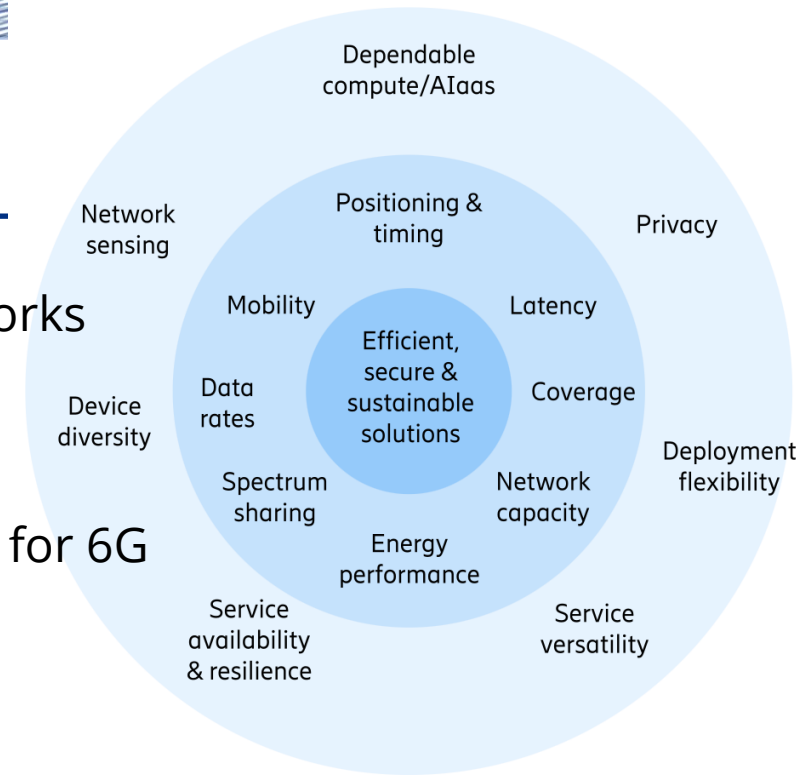
6G will further advance the performance, service differentiation and guarantees of traditional use cases such as eMBB, FWA and IoT. An entirely new wave of use cases and devices will be made possible by 6G technologies, including synchronized distributed massive MIMO, non-terrestrial networks, integrated communication and sensing. This is expected to include wide-area mixed reality, massive twinning, autonomous mobility, simultaneous location and mapping services, and more.

6G architecture

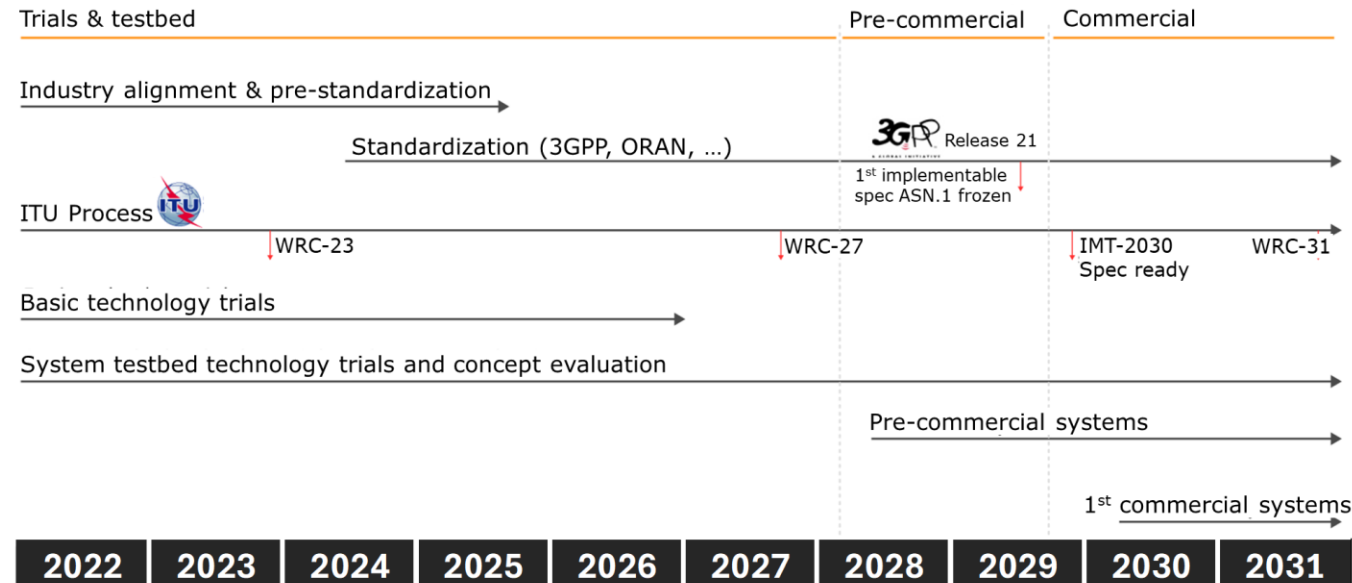


AI-native networks

New spectrum for 6G



High-level 6G timeline



Mobile Networks & MOPA

→ Plethora of optical solutions in mobile network deployments.

- In many instances this is due to an operator's demographics, geography, & legacy operations.
 - Challenging for operators, system vendors and optical pluggable suppliers to focus on the most relevant device solutions.
- Higher costs

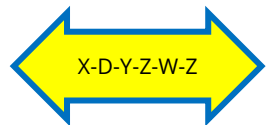
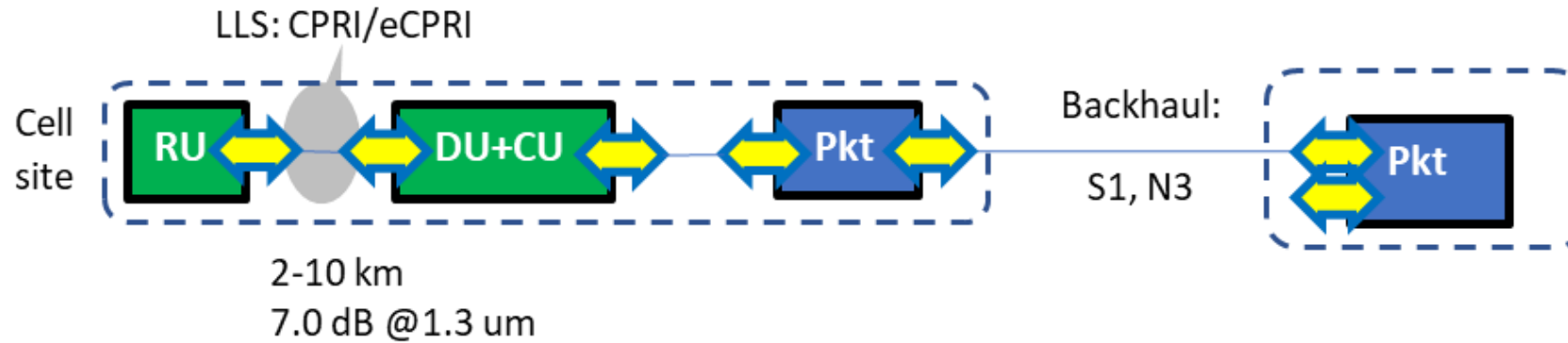
→ MOPA (Mobile Optical Pluggables Alliance)

- Formed to provide an improved common understanding.
- Define *blueprints*, or network solution use-cases that utilize optical pluggables and passive components including high-level requirements for these solutions.

→ The goal is fewer options, which will lead to greater economies of scale and reduced costs.

- *A number of industry standards are used to specify the optical transceivers used in the different blueprints. Leveraging optical solutions from other high-volume applications (e.g. data center) can help*
- **Mobile networks typically have more challenging req'ts which can lead to increased costs.**
 - Multi-rate operation (Ethernet, CPRI)
 - Higher optical insertion loss budgets plus margin for cable plant changes
 - Wider operating temp range (e.g. -40C to +85C)
 - Low power dissipation, small, compact form-factors

Blueprints *(example)*



Optical Pluggable module (*X-D-Y-Z-W-Z refers to the pluggable's capability including data-rate, reach, wavelength, formfactor, etc.*)



RAN Network Element



Transport node: WDM or Pkt

Blueprints (con't) & Relevant Standards

10 km RU DU Direct parallel fibers Blueprint			
Typical UC	DRAN DU to RU. 2-10 km		
Distance	Typ Min 2 km; Typ. Max: 10 km		
Channel IL	7.0 dB @1.3 um (For Typ. Max Distance)		
Mode, Nr ch., WL	Dual fiber: O-band 1310 nm. BiDi O-band 1270nm/1330 nm.		
Temp. Range/Class	I-temp		
Lifespan	15 years		
Data rates	10 Gb/s	25 Gb/s	50 Gb/s
Formfactor	SFP+	SFP28	SFP56
FEC, Mod format	No, NRZ	Yes, NRZ	Yes, PAM4
Power Class	PC2 (1.5 W)	PC2 (1.5 W)	PC2 (1.5 W)
Pluggables codes	10G-10km-O-G-1-2-SFP+ 10G-10km-O-B2-2-1-SFP+	25G-10km-O-G-1-2-SFP28 25G-10km-O-B2-2-1-SFP28	50G-10km-O-G-1-2-SFP56 50G-10km-O-B2-2-1-SFP56
Key technologies	-	Low-cost 25G DFB	TBD
Standards	IEEE 802.3, Clauses 52 & 158 ITU-T G.9806 (Amend 2) See Appendix A Tables 5,6,7	IEEE 802.3, Clause 114 & 159 ITU-T G.9806 (Amend 2) See Appendix A Tables 5,6,7	IEEE 802.3, Clauses 139 & 160 ITU-T G.9806 (Amend 2) See Appendix A Tables 5,6,7
Market status and outlook	Mature	Ramping, complement to 10G	Introduced, complement to 25G

Table 7: 10 km RU-DU direct parallel fibers Blueprint. (*) For DRAN, distances between 2 and 10 km are expected to be much fewer than those ≤ 2 km.

6G Needs (*front-haul*)

- **Higher bandwidths**
- **Greater aggregate data-rates**
- **Small form-factors** (e.g. SFPx)
- **I-temp operation** (-40C to +85C)
- **Low power consumption** (e.g. maintain 2.5W for every new DU generation, doubling the port speeds every 3-4 years)

- In many cases, front-haul resides in fiber-starved environments---**WDM** can enable efficient use of fiber resources
- Some mobile operators have a need for up to **30km reaches**.
- DWDM in C-band can incur larger CD penalties for longer reaches, especially at higher data-rates.
 - Optical or electrical domain equalization will be needed to overcome these CD impairments.
 - Prefer to use **electronic** means but power dissipation, size (density), latency and cost could be disadvantageous.
 - Analog EQ (vs. DSP) may be an option to minimize power dissipation.
 - O-band operation may have merit to minimize CD impairments (operate away from fiber ZDW to avoid Four-Wave Mixing penalties).
- Ultimately may have **different technology options** depending on required reach.
 - IM-DD for shorter reach => low-power cost-effective solutions
 - “Coherent Lite” for longer reach => higher power dissipation and cost-performance solutions. (Can box manufacturers still utilize “one slot” for all technologies/reach solutions?)

Relevant Standards for 6G *(Update)*

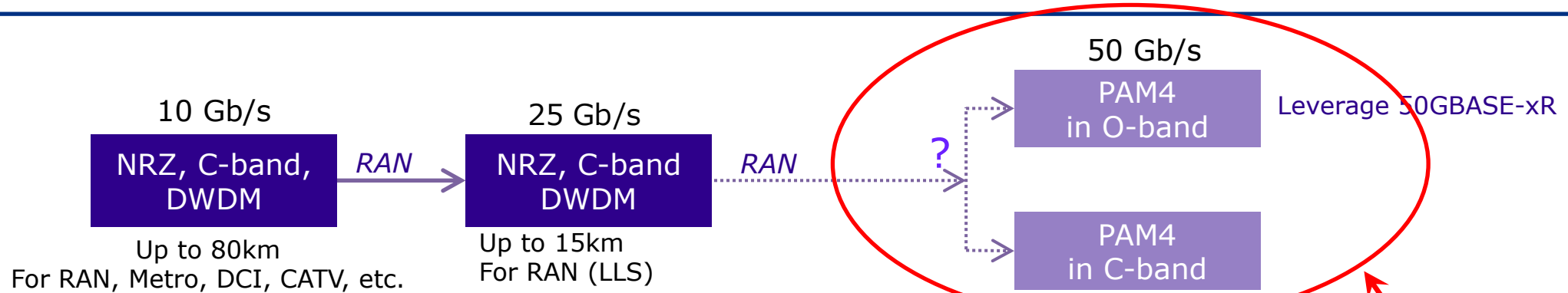
Completed (In-force)

- IEEE 802.3 Ethernet
 - Clause 88 (100Gb/s, 4x25Gb/s, 10km, 40km, LWDM)
 - Clause 140 (100Gb/s, PAM4, 2km)
 - Clauses 158, 159 & 160 (10, 25, 50Gb/s BiDi, 10, 20 & 40km)
- ITU-T Recommendations
 - G.695 (50Gb/s, CWDM, O-band, 10km)
 - G.698.1 (25Gb/s, DWDM, C-band, ~10km)
 - G.698.4 (40ch x 10G, 20ch x 25G, DWDM BiDi, C-band, 20km, 10km)
 - G.698.5 (25Gb/s, DWDM, O-band, 10, 20km)
 - G.9806 Amd 3 (100Gb/s BiDi)

In discussion / In progress

- IEEE 802.3dk (100Gb/s BiDi, 10, 20 & 40km) *(to be ratified early 2026)* ***(consistent with G.9806)***
 - ITU-T G.695 (100Gb/s, CWDM, O-band, including BiDi)
 - ITU-T 50Gb/s WDM, added application codes to existing (G.698.1 or G.698.5) or new Recommendation.
-

Relevant WDM Standards for 6G (con't)



Pluggables vs. Blueprints	10G-10km*-C-6-2-SFP+	10G-15km-C-D-48-2-SFP+	25G-15km-C-D-48-2-SFP28
8.3.2	○		
8.3.3		○	○
8.3.4		○	○
8.3.5		○	○
9.2.4		○	○
9.2.8		○	○

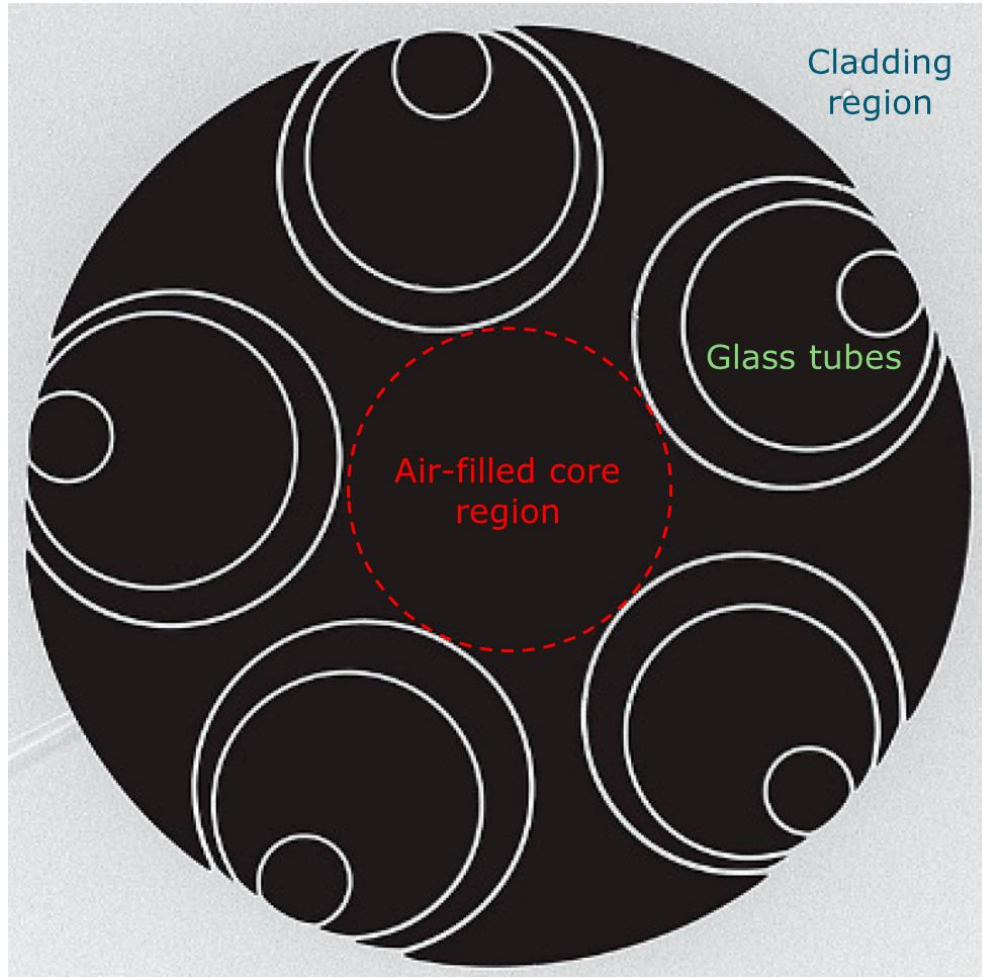
- 10Gb/s solutions have been shipping for many years
 - Fixed WDM is mature & cost effective
 - Tunable (self-tuning) are available
- 25Gb/s standards are in-force
 - Fixed & tunable are ramping
- 50Gb/s standards are in discussion

Wavelength Options for 50Gb/s DWDM Sol'ns & IL Budgets

	Fiber Attenuation	Connectors Insertion Loss	Maintenance Margin	Mux/DeMux Insertion Loss	Total Loss budget
C-band DWDM 48ch	3.8 dB *	2 dB *	1 dB *	9 dB (2 x 4.5 dB)	15.8 dB
O-band DWDM 48ch	6.0 dB *	2 dB *	1 dB *	9 dB (2 x 4.5 dB)	18.0 dB

*Table ANA.1: Preliminary Loss budget estimations for C-band DWDM and O-band DWDM. * Using the values of Table 4 in Section 6.9.*

Hollow-Core Fiber (*DNANF = Double Nested Antiresonant Nodeless Fiber*)



- Proposed by University of Southampton in 2014
- Luminosity (spin-off) acquired by Microsoft in 2022
- Increased activity in this area, with technical breakthroughs and field trials
 - British Telecom
 - Comcast
 - EuNetworks
 - China Mobile
 - Microsoft

Glass Fiber vs. HCF (and potential benefits to fronthaul applications)

Characteristic	Glass Fiber (G.652D)	HCF (DNANF)	Benefits to Fronthaul
Latency	Group Velocity $\sim 2 \times 10^8$ m/s	Group Velocity $\sim 3 \times 10^8$ m/s 33% lower latency	<ul style="list-style-type: none"> • 15km reach => 22km • Temp independent => tight time-sync
Loss	0.2 – 0.4 dB/km	0.1 – 0.2 dB/km 30 – 50% lower loss	<ul style="list-style-type: none"> • Longer reach with same optics • Lower cost/lower power consumption for same reach
Chromatic Dispersion	0 – 5 ps/(nm·km) (O-band) ~ 0.1 slope 17 ps/(nm·km) (C-band)	2 – 4 ps/nm km	<ul style="list-style-type: none"> • Lower cost & power consumption for compensation electronics • Same CD across WDM channel
Nonlinearity	Launch power per channel limited to +5 to +10 dBm	No practical limit	No FWM impairments even with low CD
Cost, maturity, field proven	More than 40 years in the field	No. Only trials. Data-center deployments planned 2025-2026	<ul style="list-style-type: none"> • Manufacturing maturity • Connectorization/splicing • Greenfield deployments • Costs → 5 years out (?)

→ **Standardization discussions are starting (e.g. ITU-T)**

An ideal HCF interconnect for mobile networks?

- Enabling low complexity (low cost and power consumption) optical modules
 - Low chromatic dispersion, **less than 1 ps/nm*km** (to be lower than G.652 O-band)
 - Lower loss than G.652 O-band (~0.35 dB/km)
- Enabling high temperature tolerant lasers
 - GaAs at **~1 um**
 - 110 DegC would be good, 125 DegC would be great
- Enabling high launch power to improve link budget
 - Pump lasers, QD, Pixel ?
 - High power (+ 20 dBm?) tolerant modulators
- Native coupling to optical modules for low cost
 - No glass fiber jumper if it can be avoided

Summary

- **6G is coming! AI is accelerating the need.**
- **Planning, updating/revising use-cases (blueprints)**
- **Demonstrations => (2025-2029)**
- **Deployment => late 2029-2030**

- **Other relevant 6G network discussions in MOPA:**
 - Tight time-sync
 - Optical Auto Negotiation (OAN)
 - Lower power dissipation via optimized module power profiles and/or LPO/RTLRL (half-retimed)



Thank You!



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