Transport Network Evolution

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Main Topics

- Optical Transport Network (OTN) Evolution
- Transport Network Support of 5G Radio Access Networks

OTN Evolution Beyond 100G

Scope of OTN Standardization

WP3 – Digital Layer Aspects

Q12/15
Architecture,
SDN Control
G.872, G.7702

Q11/15
Signal Formats
G.709, G.709.x,
G.7041

Q13/15
Synchronization,
Jitter & Wander
Performance
G.8251

Q14/15
Management
and Control
G.874, G.874.x

WP2 – Physical Layer Aspects

Q6/15
Optical Physical
Interfaces, Components
G.959.1, G.695, G.698.x,
G.680, G.66x, G.67x

Q5/15
Optical Fibers
e.g., G.652

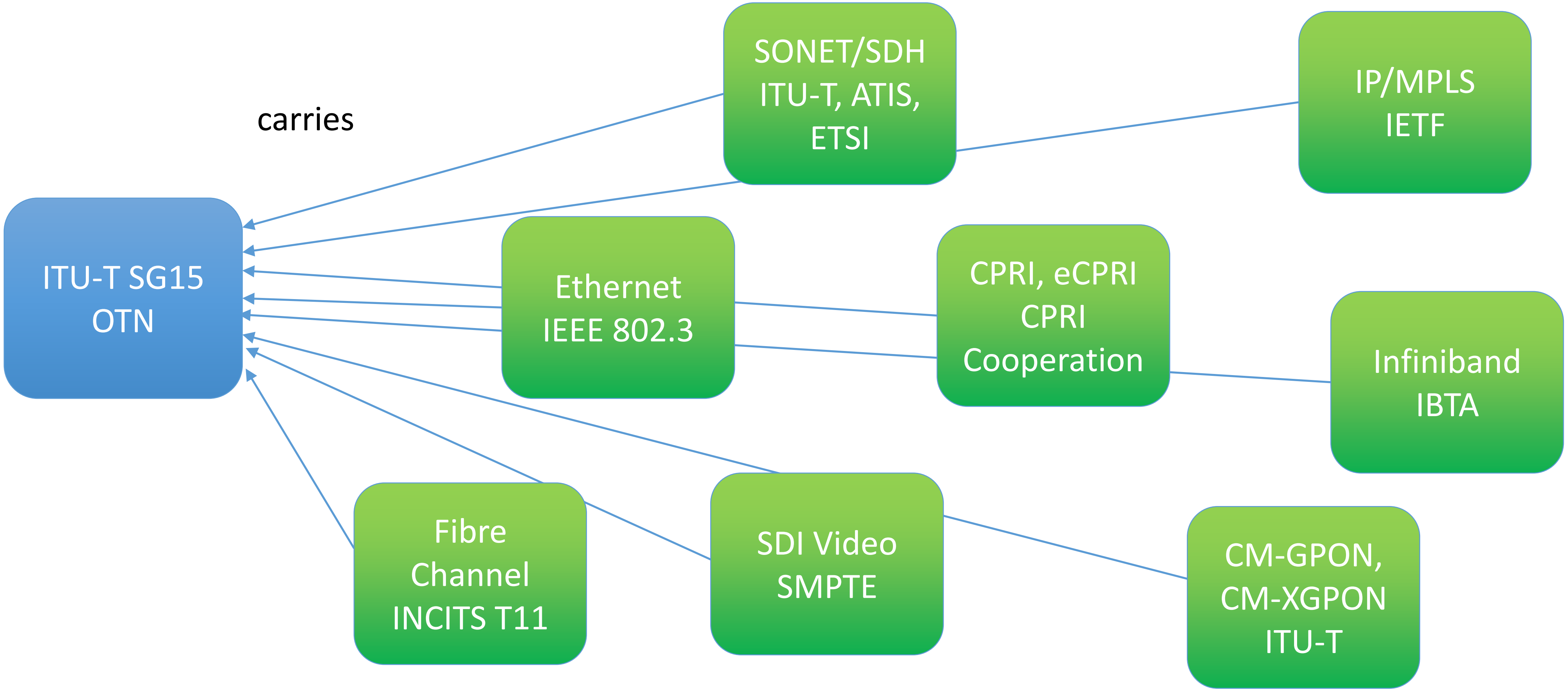
Published Recommendations available for free download at:
https://www.itu.int/ITU-T/recommendations/index.aspx?ser=G

What kinds of OTN interfaces does SG15 Standardize?

- Fully Standardized Interfaces and Aspects
  - Mappings of Client Interfaces into Line Interface Frame formats
  - Fully Standardized OTN Client Interfaces – Optical Budgets recently based on IEEE 802.3 with an OTN frame Format
  - Line interfaces where technology is sufficiently mature for multi-vendor interoperability (typically 200-450km over amplified metro ROADM networks (80km under consideration), initially 2.5G and 10G NRZ, under development 100G DP-QPSK)
- Functionally Standardized Interfaces
  - Long/Ultra-Long Haul (1000s of km terrestrial or subsea)
  - The Information flow across an interface, the OAM and how it is processed are standardized so that different vendor systems are managed in the same way, but the precise modulation, FEC, Frame Format is left to individual vendor designs
  - Examples: Flexible Coherent with probabilistic constellation shaping and exotic proprietary FEC
  - Single-vendor subnetworks composed of functionally standardized interfaces are interconnected using shorter reach fully-standardized interfaces

Ecosystem of Services that may be carried as client services over OTN Technology

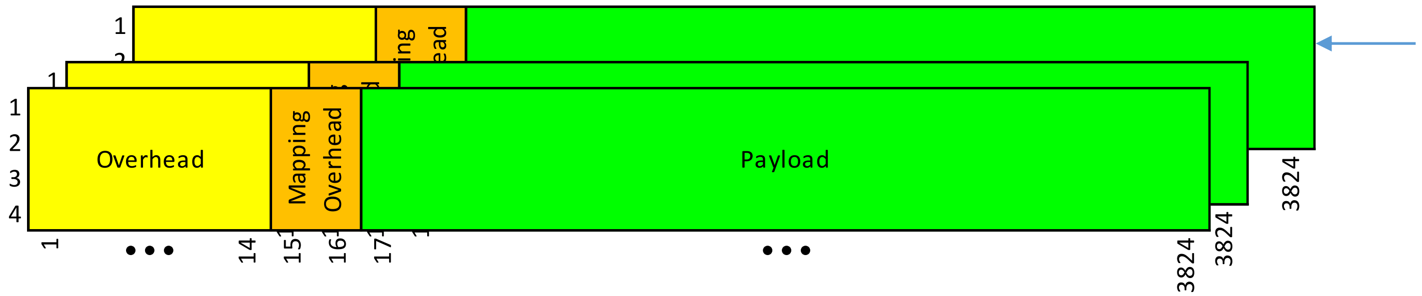
Note: OTN is a toolbox – not every product implements every possible mapping, and some services are only available in specialized equipment targeted at specific network applications



Beyond 100G Line Interface Format Formulation – OTUCn
n instances of a logically interleaved 100G (C=100) frame format

- Fully Standardized interfaces are all multiple of 100G, and may be inversely multiplexed over 100G, 200G, or 400G optical tributary signals
- Functionally standardized interfaces may have reduced tributary slot capacity on one or more of the 100G “slices” – OTUCn-M consists of n full or partial 100G slices and has M total 5G tributary slots of capacity. Aggregate size can scale in steps as small as 5G. Full specification of overhead processing and information content allows for common management paradigm to be applied to equipment of multiple vendors

n instances of a logically Interleaved frame structure, frame and multiframe syncronous



Bandwidth allocation granularity is twenty 5G “tributary slots” per 100G slice

Aggregate bit-rate = n × 239/226 × 99 532 800 kbit/s

OTN Beyond 100G Functional Model

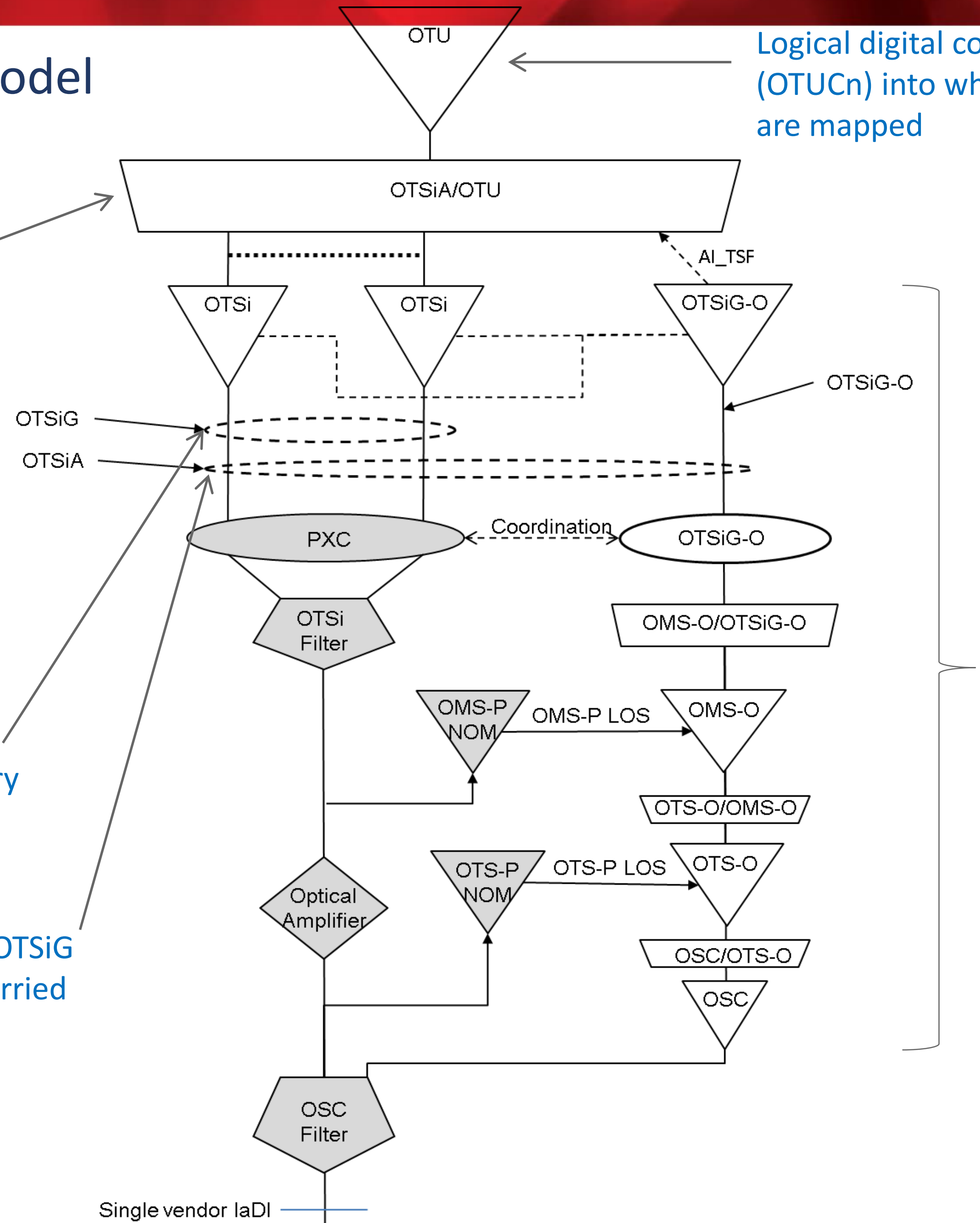
General-purpose framework for carrying a digital container on multiple lambdas

Digital container is mapped over one or more optical tributary signals (OTSi). FEC is part of the adaptation to the physical layer. For line side, the adaptation is vendor specific (e.g., might disinterleave OTUCn frame and apply FEC per OTSi, or might stripe a single SD-FEC frame over all the OTSi

OTSiG is the group of optical tributary signals carrying the OTUCn

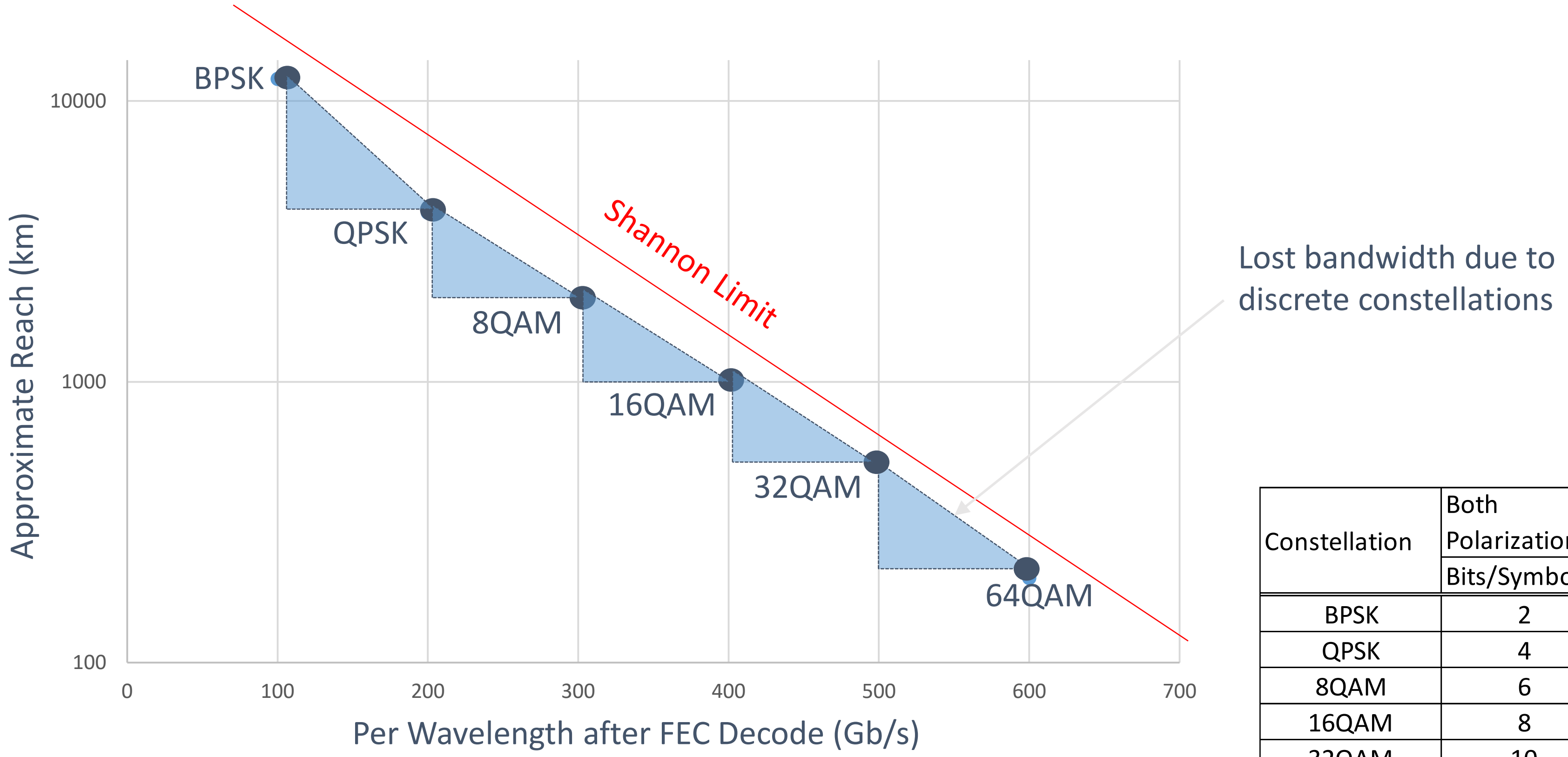
OTSiA is the assembly including the OTSiG plus the non-associated overhead carried In the optical supervisory channel

Logical digital container (OTUCn) into which clients are mapped



Non-associated overhead carried in the optical supervisory channel (OSC). Single instance of overhead for the group of optical tributary signals carrying the OTUCn. Analogous to OCh-O used for up to 100G OTN

Approaching Shannon with Discrete Constellations



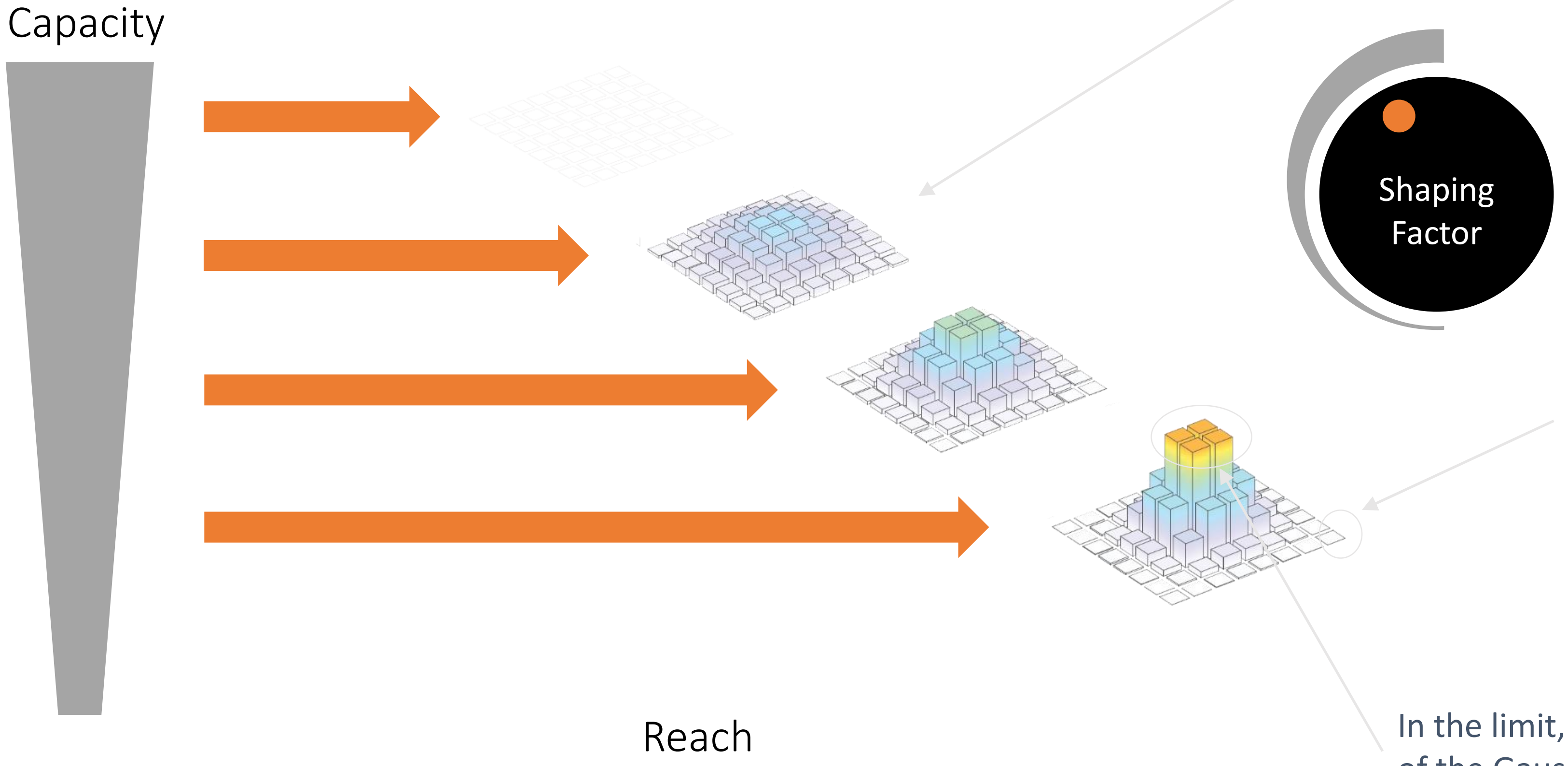
Standardized or under consideration for multi-vendor interoperability

Constellation	Both Polarizations Bits/Symbol	Baud Rate Including FEC 30 Gbaud	60 Gbaud	90 Gbaud
BPSK	2	50 Gb/s	100 Gb/s	150 Gb/s
QPSK	4	100 Gb/s	200 Gb/s	300 Gb/s
8QAM	6	150 Gb/s	300 Gb/s	450 Gb/s
16QAM	8	200 Gb/s	400 Gb/s	600 Gb/s
32QAM	10	250 Gb/s	500 Gb/s	750 Gb/s
64QAM	12	300 Gb/s	600 Gb/s	900 Gb/s

Probabilistic Constellation Shaping - Variable rate / reach tradeoff

OTUCn-M provides a way to describe the information carried over a proprietary signal format in a standardized way, including the how the clients are mapped into the digital bit-stream

2-dimensional Gaussian probability distribution of how frequently different symbol values are used decreases average Bits represented per symbol

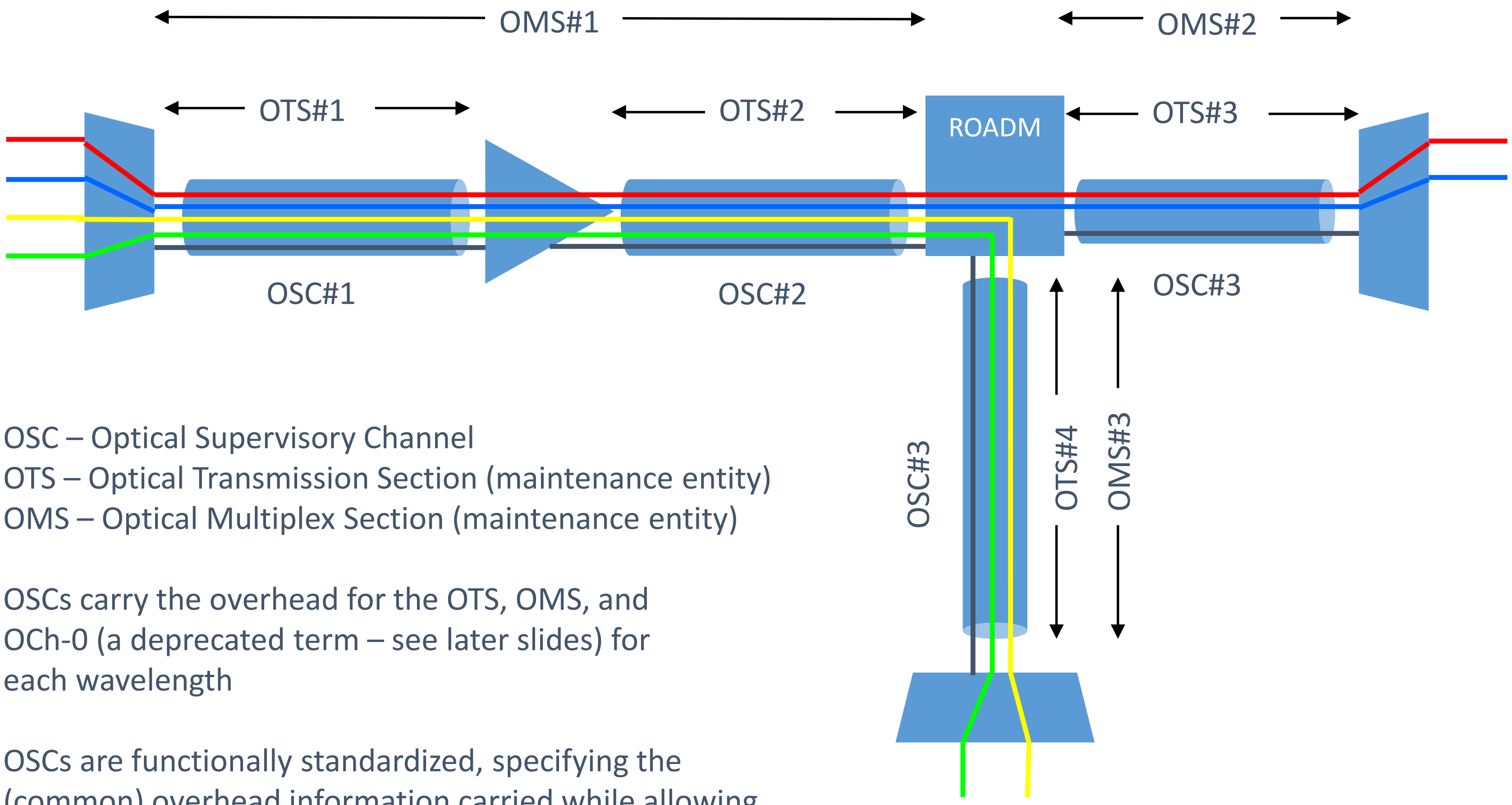


Using the outer (highest power) constellation points less frequently Improves OSNR

In the limit, xQAM degenerates to QPSK as σ of the Gaussian distribution approaches zero and only the inner four constellation points are used

Optical Media Layer Management (G.807)

Functionally Standardized Architecture for Management and Fault Isolation in Optical Networks



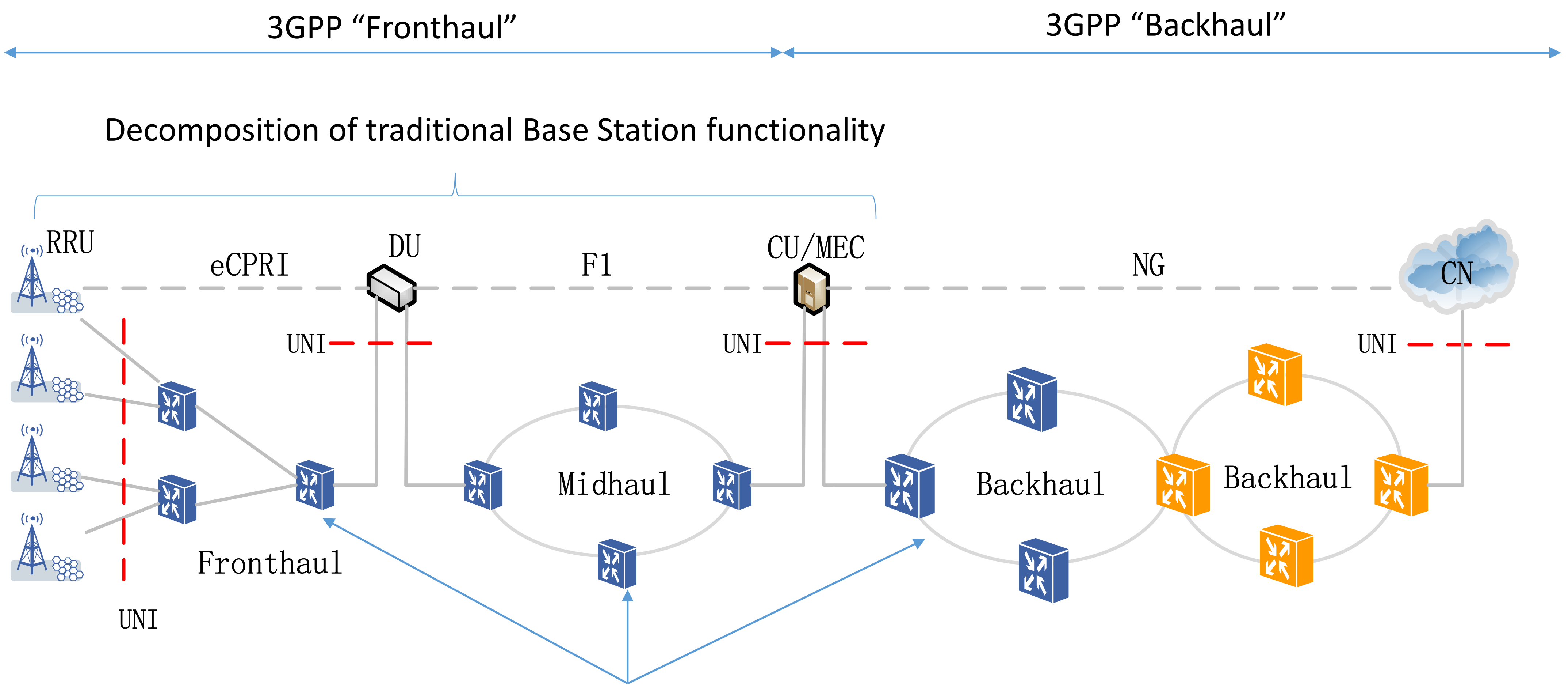
OSC – Optical Supervisory Channel
OTS – Optical Transmission Section (maintenance entity)
OMS – Optical Multiplex Section (maintenance entity)

OSCs carry the overhead for the OTS, OMS, and OCh-0 (a deprecated term – see later slides) for each wavelength

OSCs are functionally standardized, specifying the (common) overhead information carried while allowing the exact physical format to be vendor specific

Transport Network Support of 5G Radio Access Networks

GSTR-TN5G – Technical Report
Transport network support of IMT-2020/5G



What Transport Network Technologies are used in these parts of the network?

Current State of Play – Transport Network support of 5G Radio Access Networks

- Huge variety of operator views (and distressingly little convergence) on which technologies to use in which parts of the Radio Access Network (RAN) (this isn't unique for 5G – 3G never converged with the CDMA/GSM split, and 4G took several years for most operators around the world to converge on LTE).
- Some operators have existing networks they want to leverage (e.g., PON), while others envision entirely new purpose-built networks
- Some operators plan to share the network with other traffic types (e.g., Enterprise private-line or residential & business Internet access), while others envision dedicated networks
- Different network topologies for different operators – some relatively "flat", while others involving large access rings where incurring a packet store and forward delay at every intermediate node could be problematic for low-latency services
- Some technologies and architectures under consideration and development are specific only to a small groups of operators, or in some cases, even a single (sufficiently large) operator.

Related Topic – Network Slicing

- No consistent definition across the industry of "network slicing", and there is a tendency for different communities to relate it to something they know. For example, in (traditional) transport networks, people think "transport networks have been sliced forever" (e.g., SDH LOVC, or OTN LO ODUk). But a channel or a tunnel is not what we believe 3GPP means when they use the term "end to end network slice"
- A network slice is a virtual network, consisting of a combination of dedicated and shared network resources, that supports the PDU sessions between a user equipment (UE, e.g., a mobile phone) and the entity providing the service (e.g., an app server) that can be engineered to provide certain service characteristics (e.g., throughput, latency) appropriate to the application
- The air interface and fronthaul (CPRI/eCPRI, which consist of IQ samples corresponding to the radio interface) are inherently shared interfaces, where there is no packet awareness or opportunity for per-service classification. The NG core is all-packet and shared. So the opportunity for dedicated resources for particular service classes occurs in the midhaul and backhaul parts of the network.
- Since the channels/tunnels provided by a transport network technology represent only a subset of the (potentially dedicated) network resources that support a network slice, SG15 avoids using the term "slice" to refer to any transport network specific resource so as to avoid confusion with the 3GPP meaning of the term.

Different Technology Approaches

- Some operators think TDM is essential ("hard" isolation of services), while other believe TDM doesn't provide the necessary flexibility
- TDM presents a tradeoff: Less reliance on traffic engineering or techniques like Time Sensitive Networking (TSN e.g., IEEE Std 802.1CM Time Sensitive Networking for Fronthaul), and avoiding packet store and forward delays at intermediate nodes through TDM bypass (or WDM bypass), but increasing individual packet transmission time by serializing the packet transmission at the channel rate rather than the interface rate. Whether TDM or packet provides the lowest latency can depend on the specific network topology.

Specific 5G-related Transport work in SG15

- New Recommendation G.8300 (e.x., G.ctn5g) *Characteristics of transport networks to support IMT-2020/5G* (currently in the AAP approval process)
- G.suppl55 - *Radio-over-fibre (RoF) technologies and their applications*
- G.suppl56 - *OTN transport of CPRI signals*
- G.suppl66 - *5G wireless fronthaul requirements in a passive optical network context*
- G.suppl67 - *Application of optical transport network Recommendations to 5G transport*
- Revision of G.709, new Recommendation G.709.4, OTU 25 and OTU 50G short reach interfaces (currently in the AAP approval process) – OTN channelized (1.25G tributary slot granularity) 25G and 50G interfaces motivated by desire to carry ODUflex(GFP) flows in 5G transport network
- New Layer Network technology "G.mtn" using FlexE framing as a way to create TDM channelized interfaces (5G calendar slot granularity)

Some 5G-related work in other Standards Groups

- IEEE Std 802.3CM-2018 – *Time Sensitive Networking for Fronthaul*
- IEEE 1914 Working Group – *Next Generation Fronthaul Interface (NGFI)*
  - IEEE Std 1914.1-2019 - *Approved Draft Standard for Packet-based Fronthaul Transport Networks*
  - IEEE Std 1914.3-2018 - *Standard for Radio over Ethernet Encapsulations and Mappings*
- MEF 22.3.1 - *Transport for 5G Mobile Networks*

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