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G.HN STANDARDIZATION: PRESENT AND FUTURE

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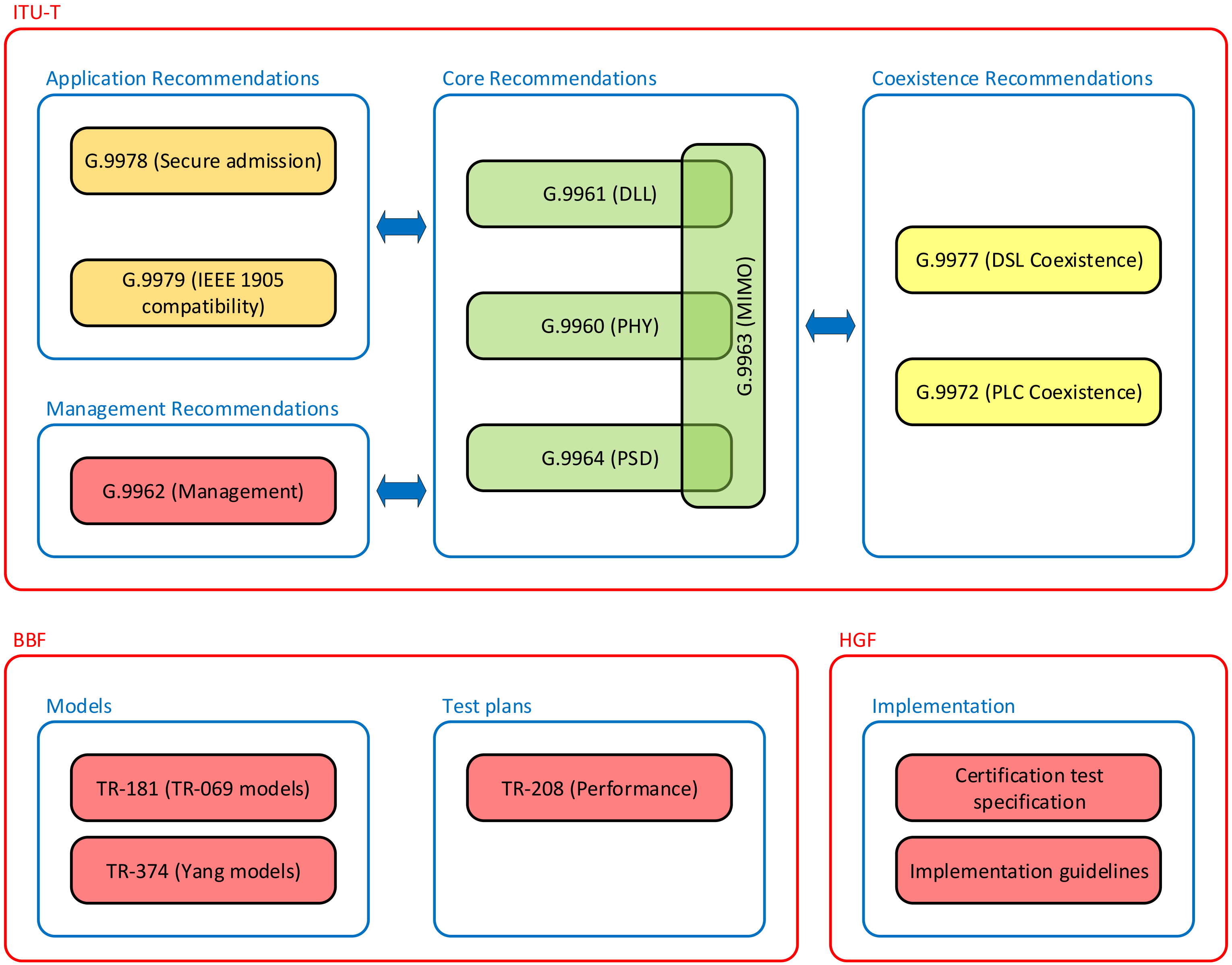
AGENDA

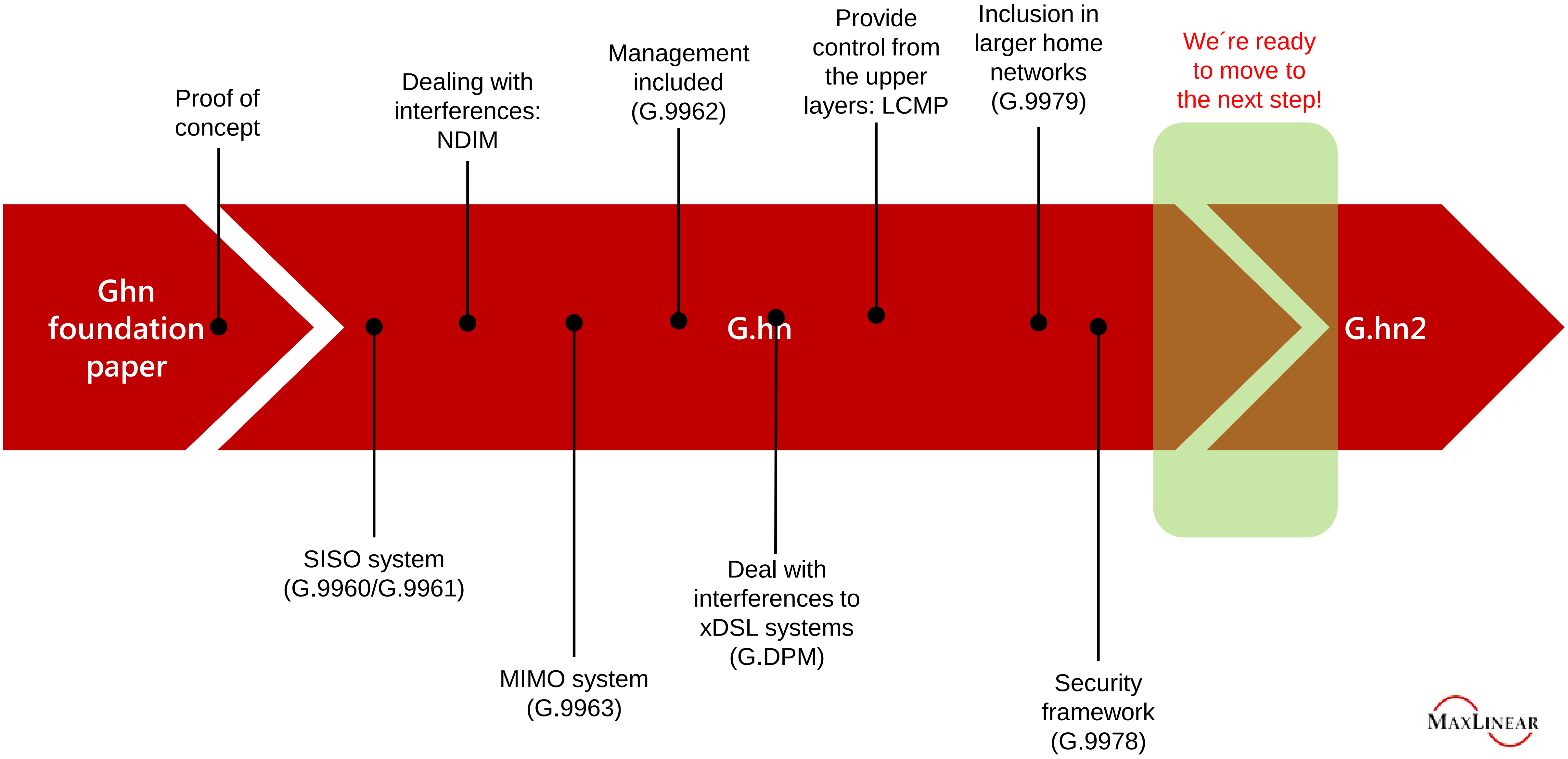
- G.hn present
  - G.hn history: Main milestones
  - G.hn Recommendation ecosystem
  - G.hn Reference model
  - G.hn PHY Layer
  - G.hn MAC Layer
  - G.hn management
- G.hn future: G.hn2
  - New fields of application & ecosystem
  - New features
  - Ghn2 vs G.hn

G.HN PRESENT

G.HN RECOMMENDATION ECOSYSTEM

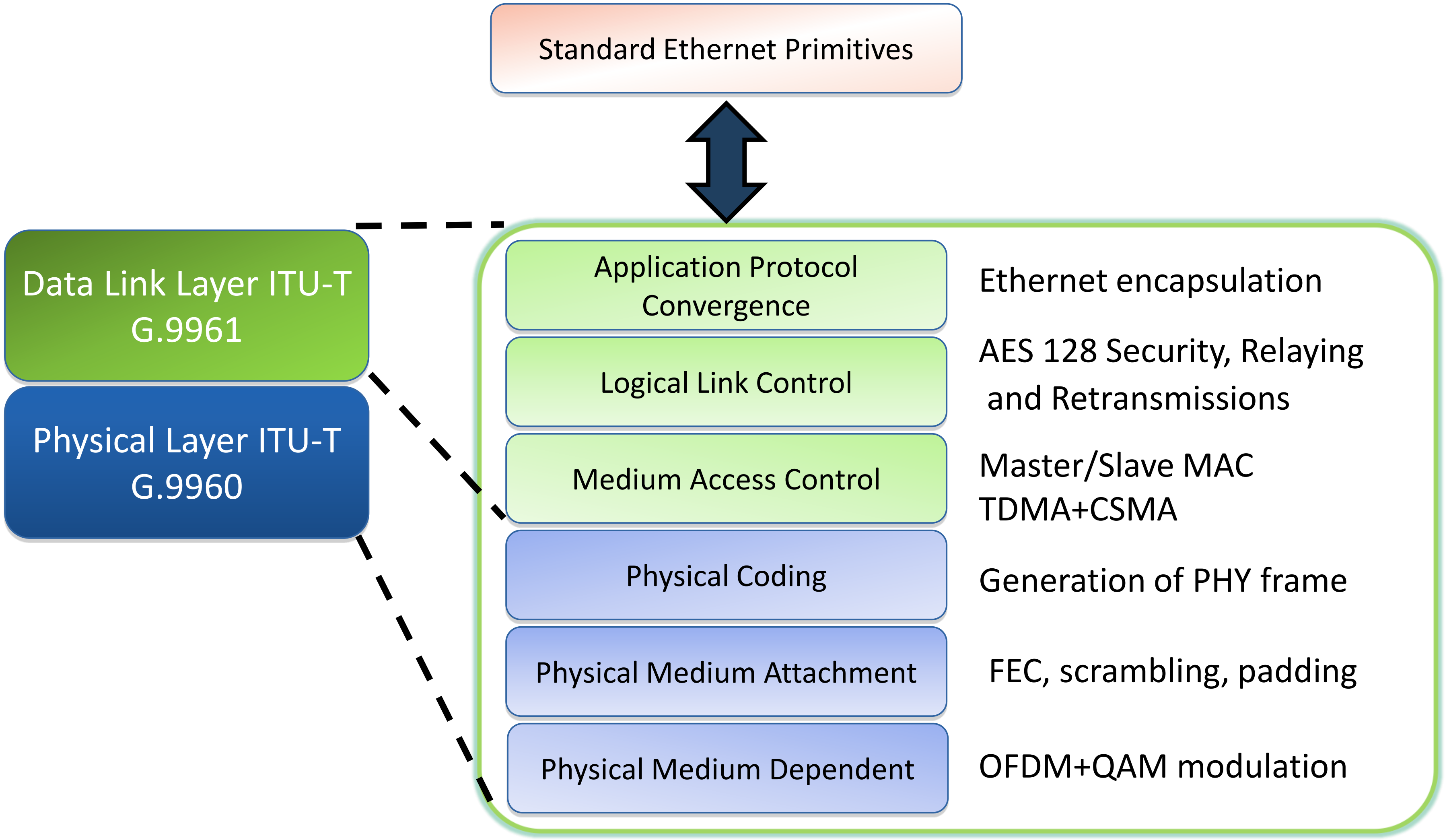


G.HN HISTORY: MAIN MILESTONES



MaxLinear

G.HN REFERENCE MODEL



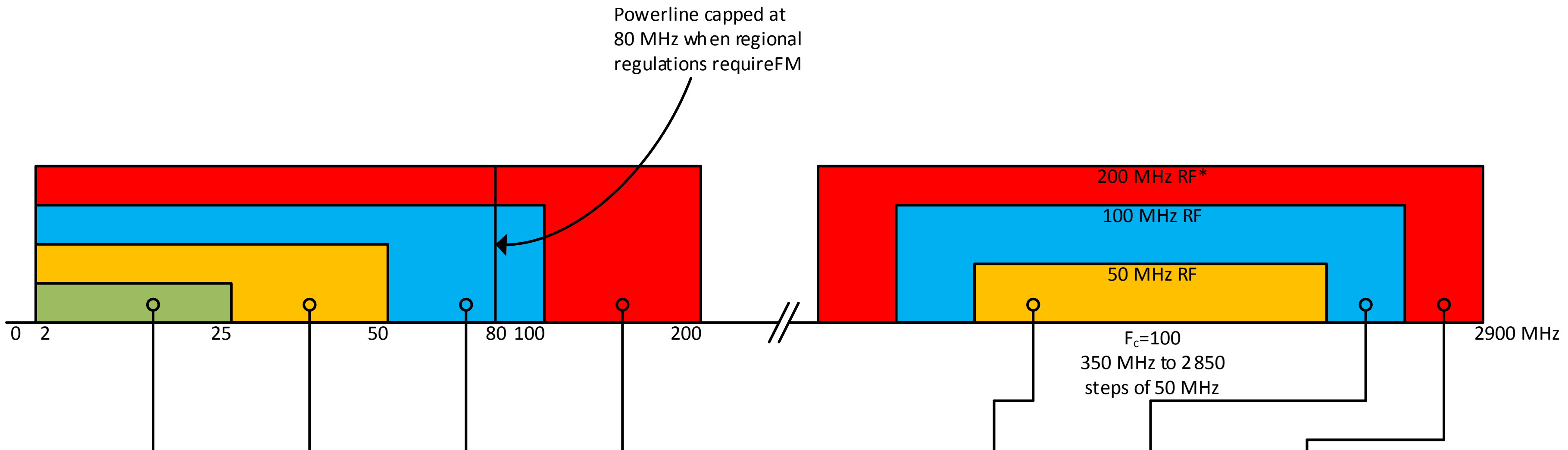
G.HN PHY

- G.hn = Highly flexible and robust MIMO OFDM engine based on three pillars:
  - Adaptive bit loading per subcarrier
    - Resilient against problems in power lines cable network (ingress, bad cables, bad splitters, etc)
    - Each End point can use the best possible modulation allowed by its own SNR
    - No need to add SNR margin to ensure low quality links get zero packet-loss
    - Systems is constantly measuring SNR between all nodes (in both directions) and adapting the bit-loading in real-time.
  - Robust line coding: FEC (Forward Error Correction): QC-LDPC-BC
    - Performance near Shannon theoretical limit
    - Three block sizes: 21 bytes (header), 120 and 540 bytes (payload)
    - Five Code rates: 1/2, 2/3, 5/6; 16/18 and 20/21
  - Adaptive subcarrier spacing to optimize the transmission on each medium

G.hn flexible PHY allows the technology to be used in many applications (SG, WiFi backhaul, IPTV) over many media (PLC, coax, phone, PoF, LiFi)

G.HN MEDIUMS & BANDS

- How we address the multimedium



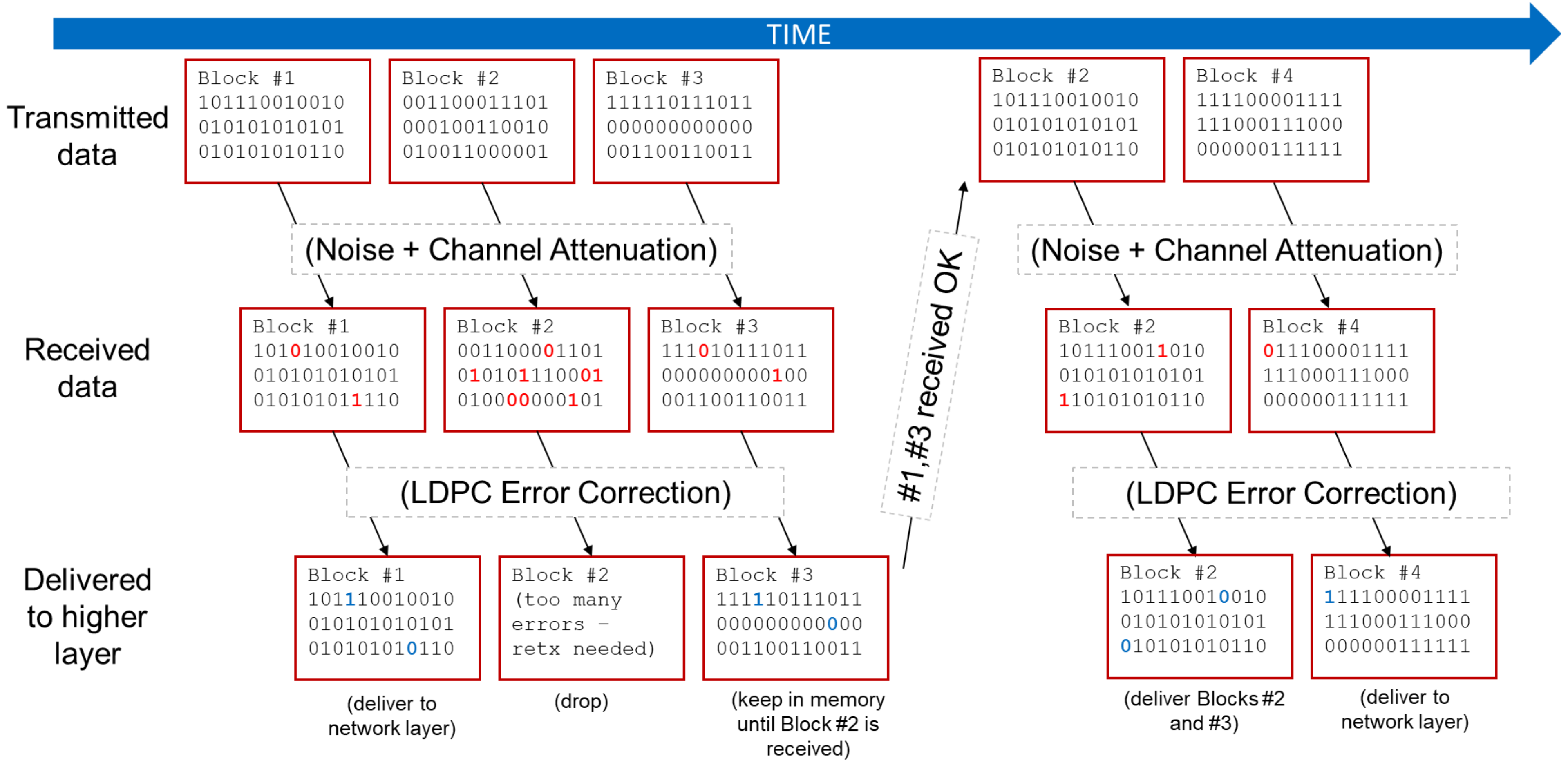
# subcarriers		25 MHz-BB	50 MHz-BB	100 MHz-BB	200 MHz-BB
Medium	Powerline	1024	2048	4096	-
	Phoneline	-	1024	2048	4096
	Coax	-	256	512	1024
	POF	-	-	512	1024
	VLC	-	256	512	1024

50 MHz-RF	100 MHz-RF	200 MHz-RF*
-	-	-
-	-	-
256	512	1024
-	-	-

200 MHz-RF is only defined in Japan

G.9961 LINE CODING & RETRANSMISSION

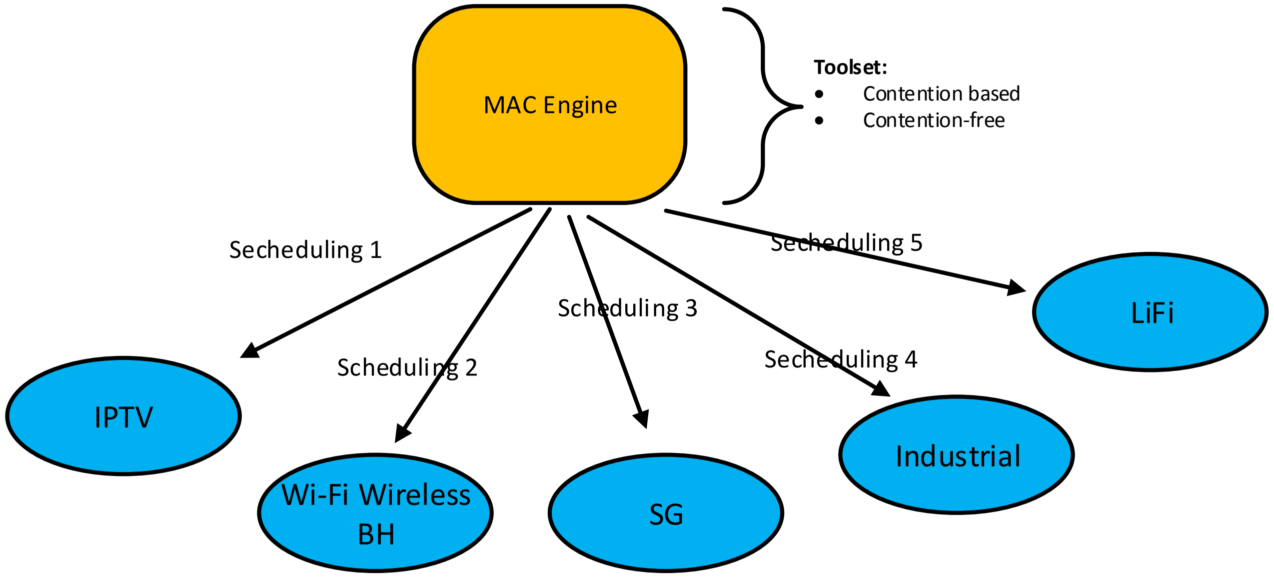
G.hn LDPC Forward Error correction + retransmission



MAXLINEAR

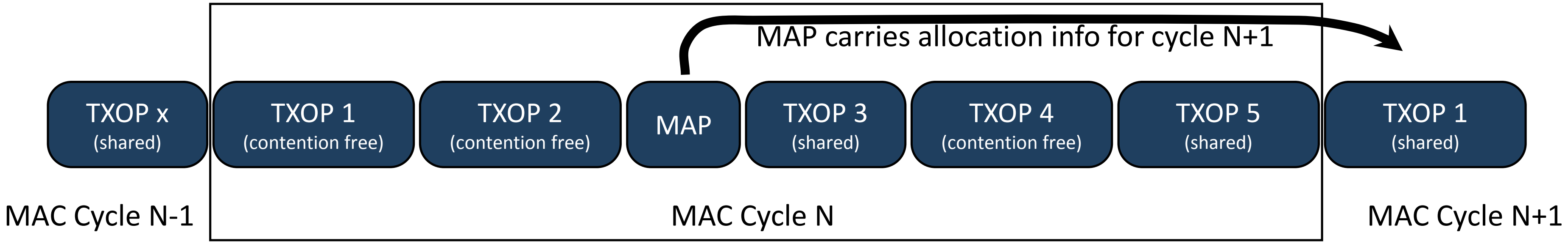
G.HN MAC

- Highly flexible Medium Access mechanisms
  - G.hn network is based on a master/slave architecture with synchronized media access
  - Allows the technology to adapt to all possible topologies and applications (TDMA, CSMA, token-passing)
  - Guaranteed Reservations for QoS-sensitive applications
  - Capable of operating reliably even in network congestion conditions



G.HN MAC (II)

- Medium Access Plan based MAC: MAP announces the scheduling for next cycle

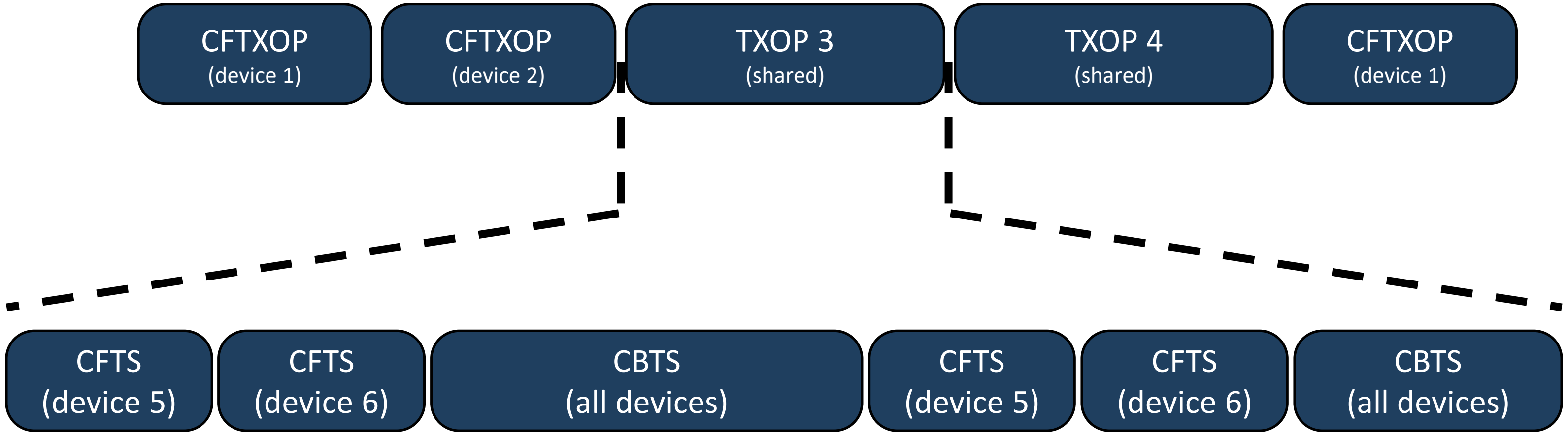


- The time period of synchronized access is called a MAC cycle
- The "Domain master" periodically broadcast a "Media Access Plan" (MAP) message, that contains allocation information for the next MAC cycle.
- Using the MAP, the Domain Master can divide the MAC cycle into multiple "Transmission Opportunities" (TXOP)
- Two kinds of TXOP:
  - CFTXOP (Contention Free TXOP) - Used for "TDMA mode". Only one node can transmit during this TXOP
  - STXOP (Shared TXOP) - Access is defined amongst a group of nodes. Used for "token-passing and CSMA mode".

The appropriate mix of these different mechanisms allows G.hn to address any application and topology

G.HN MAC (III)

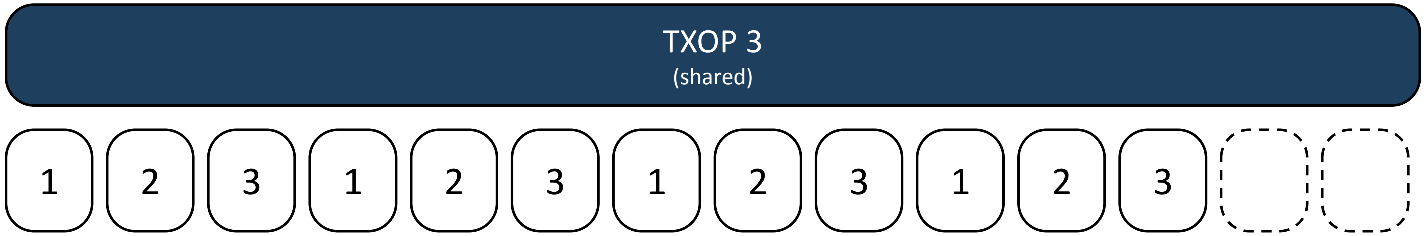
- Shared TXOPs are sub-divided into Time Slots (TS) of 2 types:
- Contention Free Time Slots (CFTS)
  - Used for “token-passing” mode
  - There are no contentions, but QoS is not guaranteed
  - Each CFTS is associated with a single node and a single flow/priority
- Contention Based Time Slots (CBTS)
  - Used for “CSMA” mode
  - May have contentions. QoS is not guaranteed, although 4 priorities are supported
  - Useful for initial registration in the network



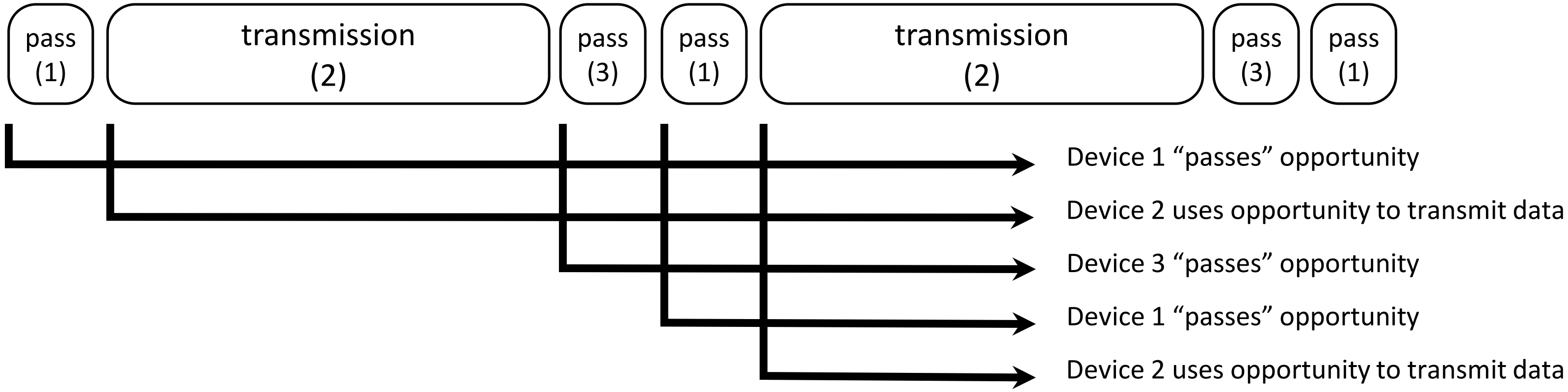
G.HN MAC (IV)

Contention-Free Time Slots (Inside a Shared TXOP)

1. In this example, the MAP specifies that a STXOP should be composed of a series of CFTS allocated to devices 1, 2, 3 (in a loop):

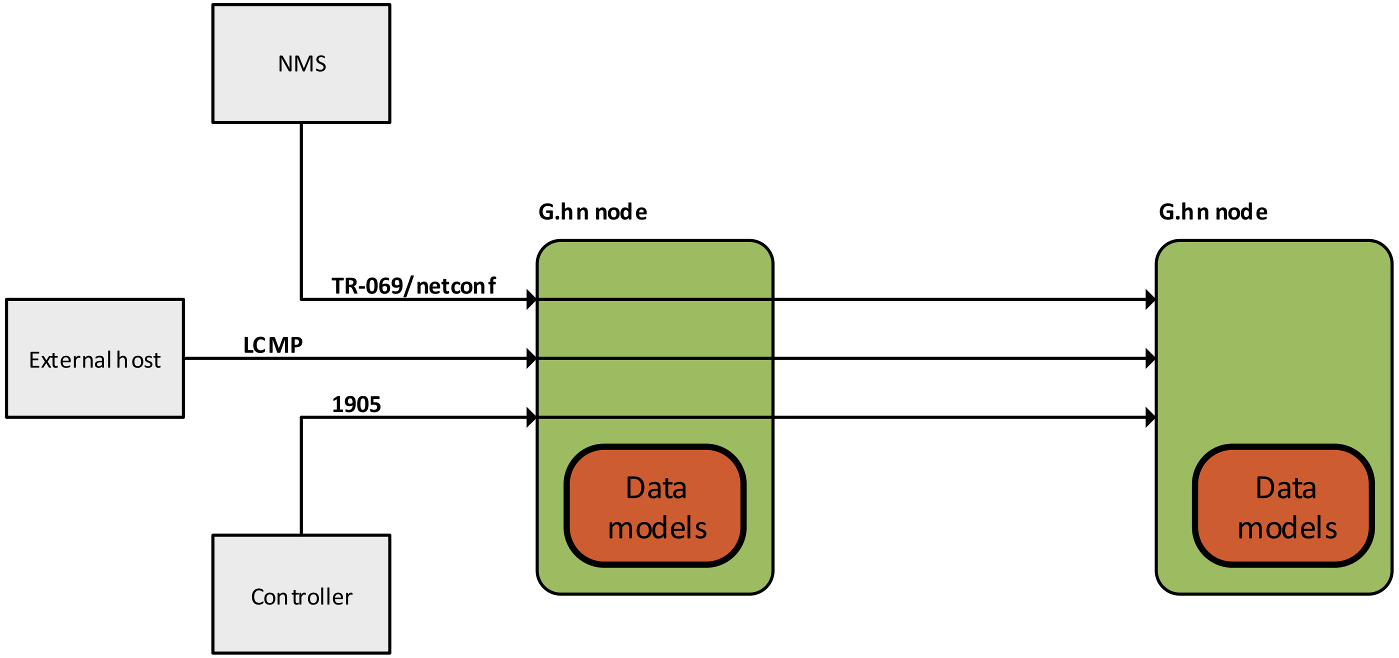


2. At this particular moment, only device 2 has data for transmission. Devices 1 and 3 “pass” on their opportunities for transmission



G.HN MANAGEMENT

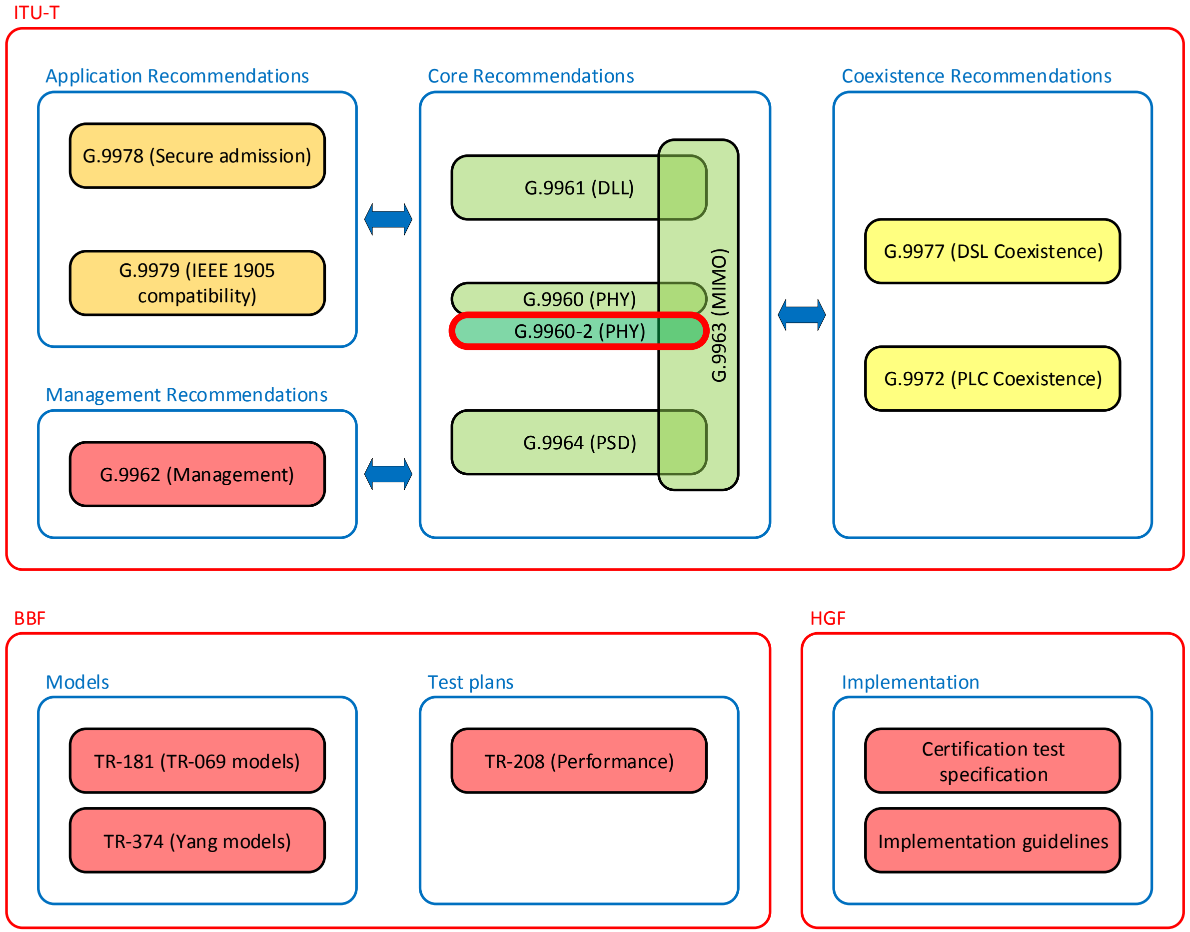
- **Data models**
  - TR-069 (TR-181)
  - Netconf (Yang)
  - G.9962, HGF (Certification)
- **LCMP Protocol**
  - Layer 2 Configuration and Management Protocol
  - Universal way to access any G.hn model at layer 2
- **Integration with Easymesh controllers (through 1905)**
  - Integration with WFA´s Wi-Fi mesh



G.HN FUTURE: G.HN2

NEW G.HN2 RECOMMENDATION ECOSYSTEM

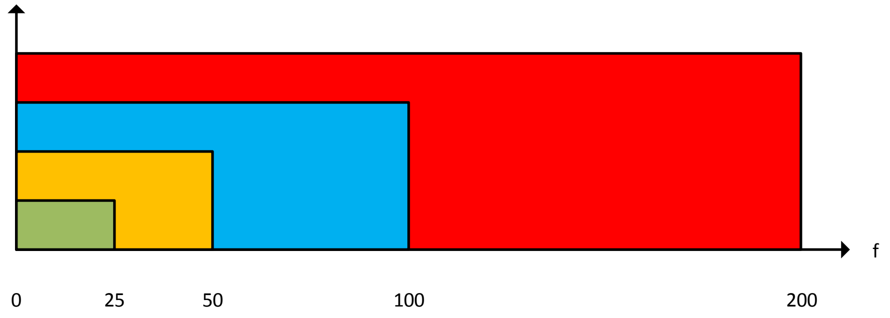
- New PHY (G.hn2) being developed by ITU-T Q18/15 to improve performance
- New PHY copes with all the Physical Media described in G.hn program
- G.hn2 is backwards compatible with G.hn
- Performance target in Powerline:
  - Maximum 4 Gb/s PHY rate on power line.
  - Guaranteed PHY rate up to 25% maximum PHY rate



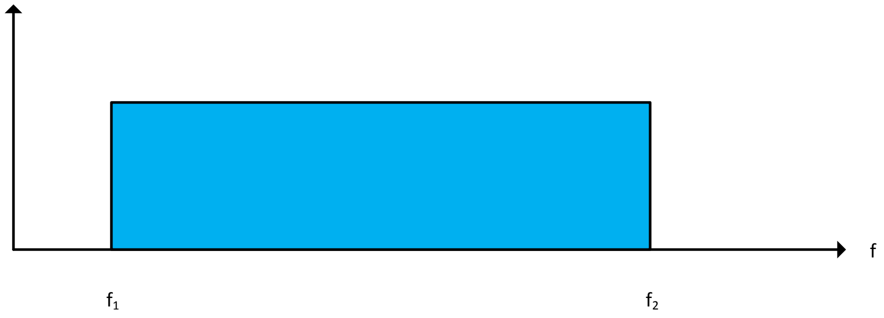
Performance targets impose changes in the PHY coding and spectrum used

G.HN2: BANDPLAN MANAGEMENT

- Bandplan concept removed in G.hn2
- Transmission is only defined by start/stop frequency
- Facilitates the use of RF
- Allows several system sharing the spectrum
- No theoretical limit on frequency: Implementation & regulatory decision



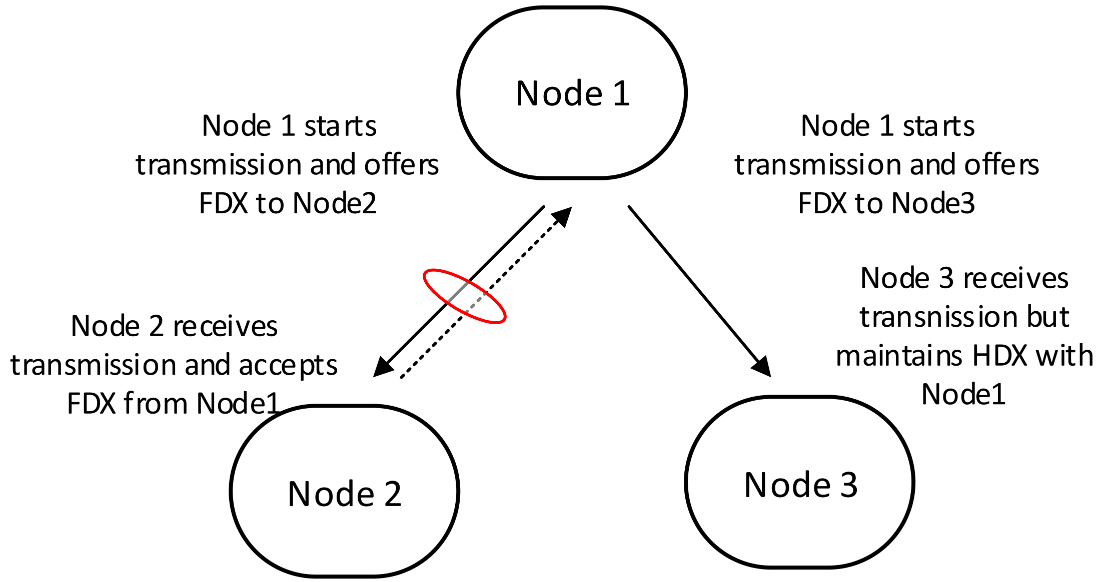
G.hn



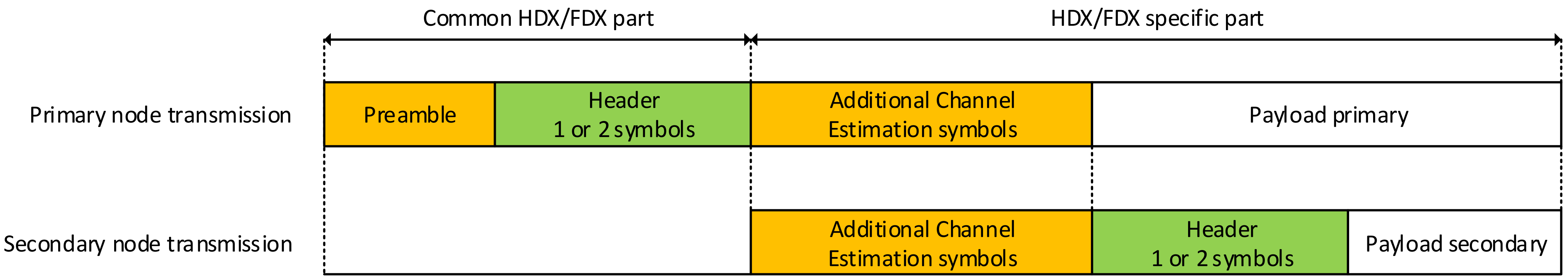
G.hn2

G.HN2 FRAMING: HDX/FDX

- G.hn2 introduces a “directed FDX” mechanism
  - A node starting a transmission offers the possibility to the destination node to start an FDX exchange

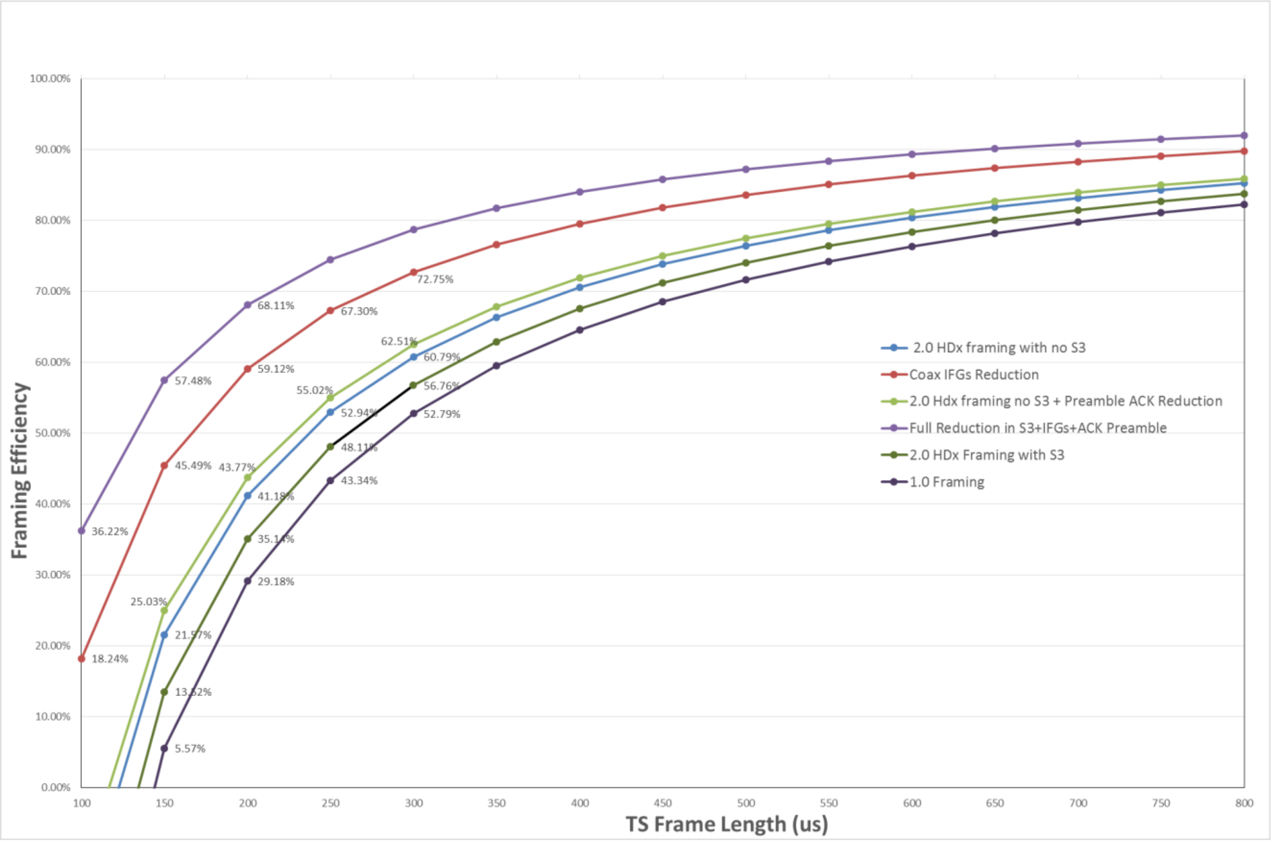


- New PHY frame format “FDX” friendly



G.HN2 FRAMING: EFFICIENCY

- G.hn2 introduces several mechanisms to gain frame efficiency
  - Variable IFG
  - Variable AIFG
  - Simplified preamble

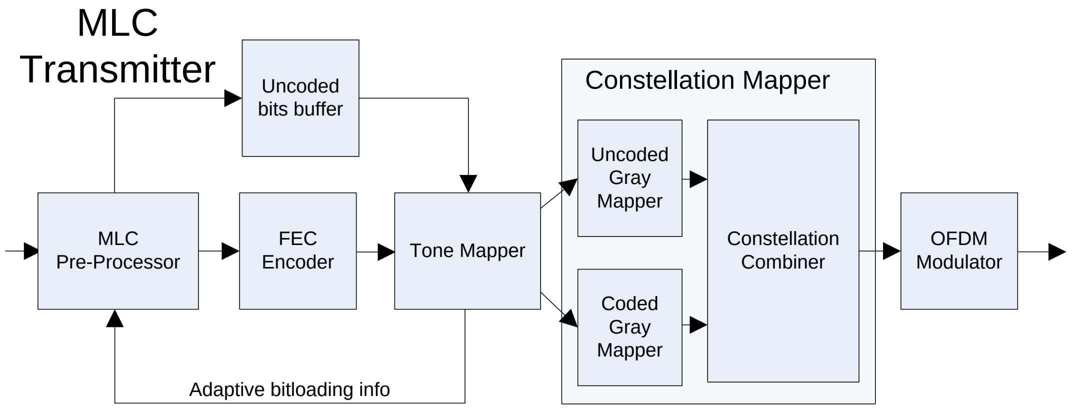


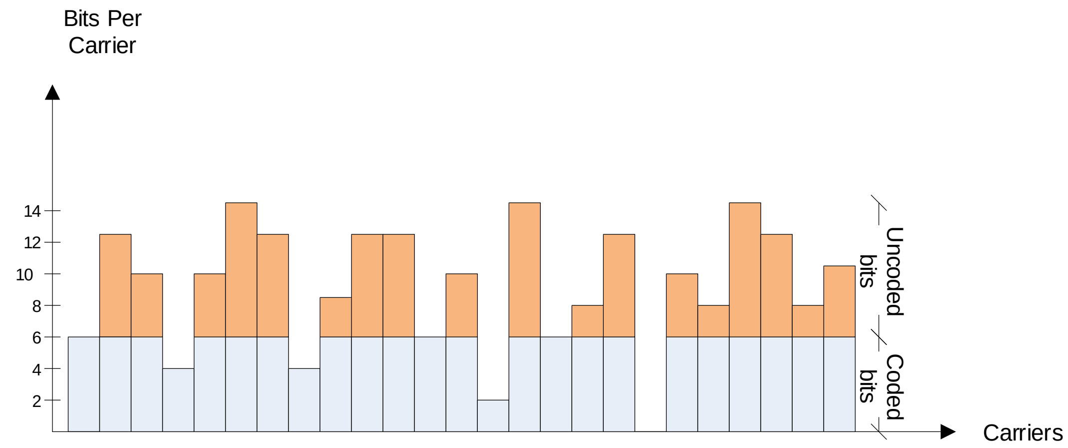
➔ Objective: increase efficiency allows to increase aggregated throughput in dense networks

MaxLinear

MULTI LEVEL CODING (MLC)

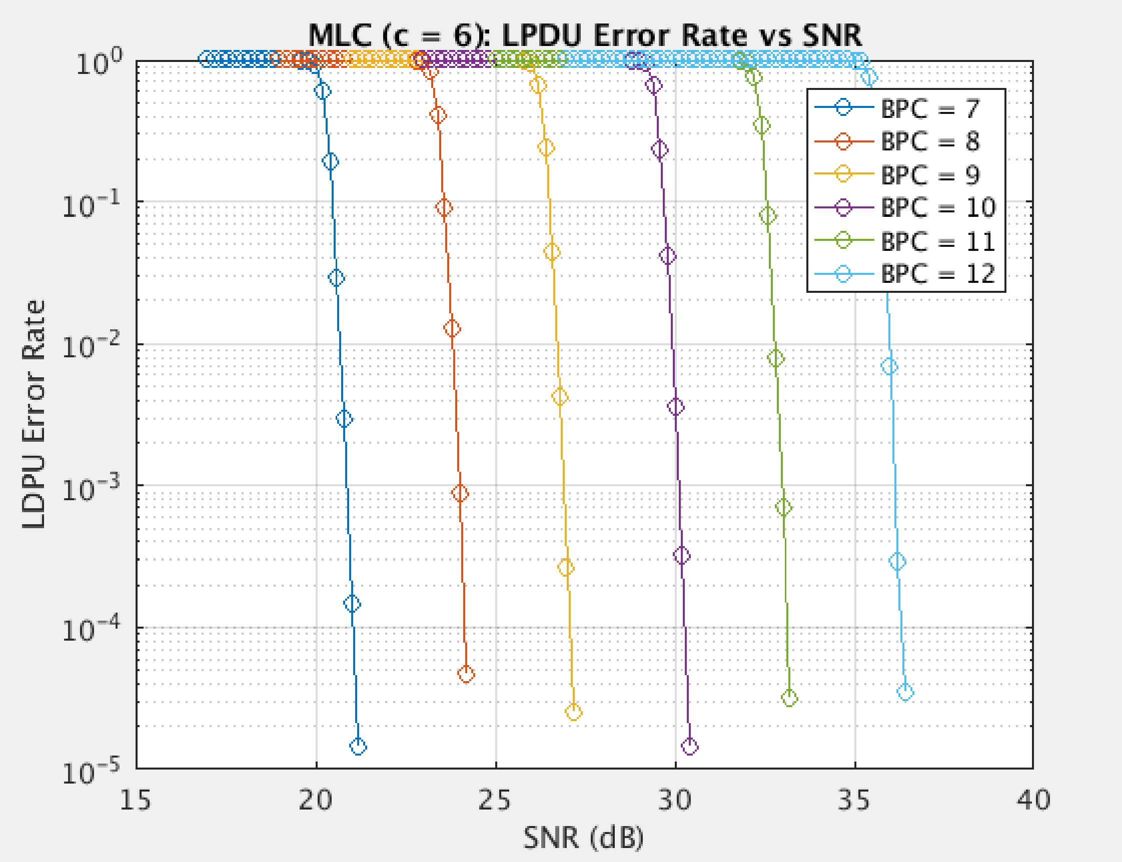
- Multi Level Coding scheme consists of not passing all the data to be transmitted through the LDPC Encoder:
  - Some bits (6) are protected using the LDPC code (coded bits) per subcarrier
  - The rest of the bits in the subcarrier are transmitted with no coding (uncoded bits).

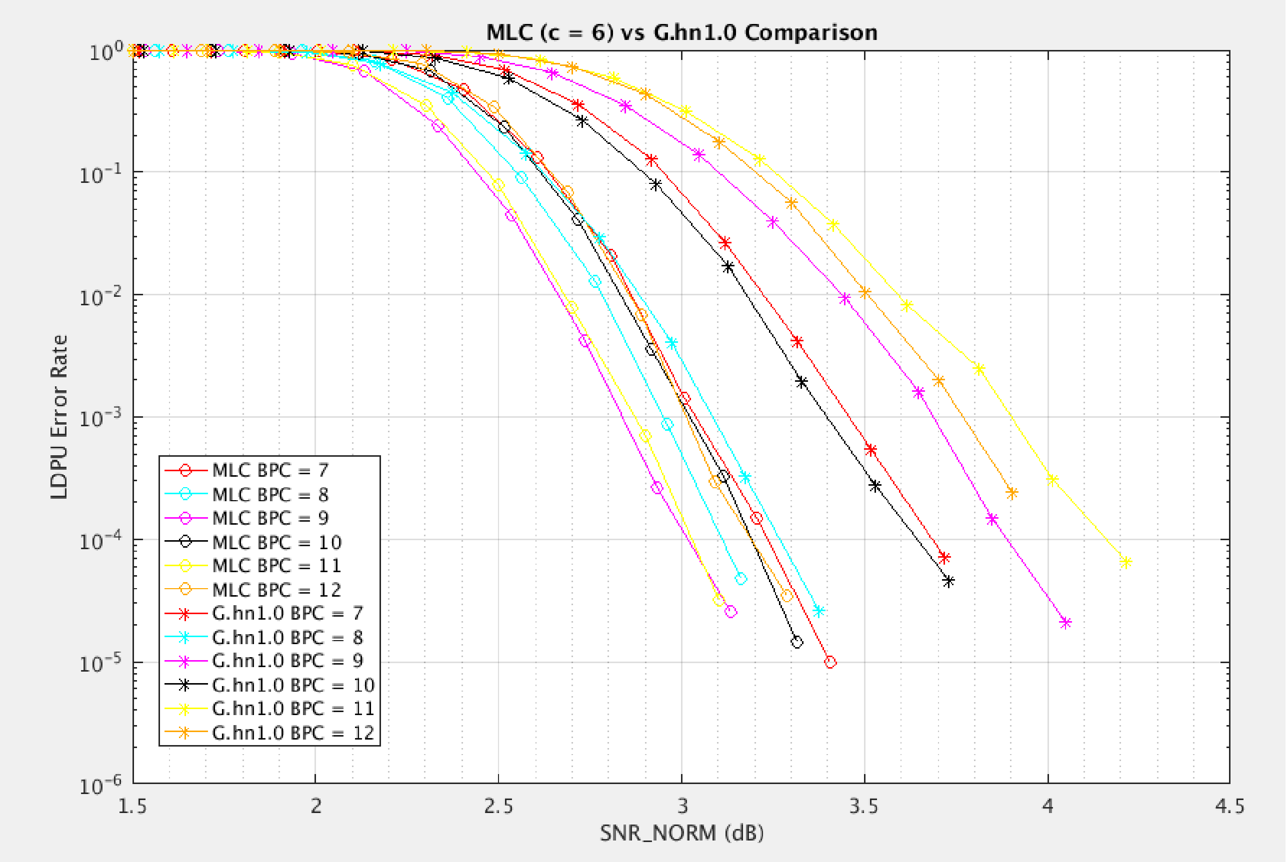




- This solves two main challenges when building a very high throughput system:
  - Reduce the area and complexity of the FEC Decoder.
  - Improve the performance of the puncturing rates.

MULTI LEVEL CODING (MLC) (II)





G.HN MANAGEMENT

- Home networking is moving to a “managed” approach driven by two factors:
  - SDN concept. Move intelligence and high level mechanisms to external entities to reduce costs and move the intelligence to more powerful entities able to run high performance algorithms (e.g., AI)
  - Improved user experience: Provide better predictability, stability and diagnosis of the flows, increasing customer satisfaction and reducing operating costs (calls)

- What is being done:
  - Refinement and standardization of data models and interfaces to external controllers to:
    - Integrate G.hn systems in larger managed in-home
    - Virtualize core functions

G.HN VS G.HN2 KEY TOPICS… SO FAR

Layer	Area	G.hn PHY	G.hn2 PHY
Physical Layer	Duplexing mechanism	HDX	HDX/FDX
	Line code	OFDM	OFDM
	Max modulation	12 bits/subcarrier	14 bits/subcarrier
	FEC	LDPC	LDPC
	LPDU size	120,540	120,540,2160
	Spectrum	5-200 MHz (Depends on the medium)	0-X GHz (depends on the medium)
	Subcarrier spacing	24.41 kHz (PLC)	24.41 kHz (PLC)
	Interframe gaps	Mainly fixed	Variable per node and link
	Decoder	Normal	Normal; MLC
	MIMO	YES	YES
	RF	Optional	YES
Data Link Layer	Logical topology	P2P, P2MP, Mesh	P2P, P2MP, Mesh
	MAC protocol	TDMA, CSMA	TDMA, CSMA
	Retransmission protocol	Yes	Yes
	Encryption	AES-128	TBD
	QoS	8-levels	TBD
	Multicast & Broadcast	Native Multicast & Broadcast support	Native Multicast & Broadcast support
	Bandwidth Allocation	Per user & per direction	Per user & per direction

G.HN FUTURE: NEW FEATURES… SO FAR

	Topic	Motivation
PHY	Bandplan removal (RCM definition)	Provide more flexibility to spectrum management Facilitate implementation of receivers
	RF-friendly	Coexistence with other services
	HDX/FDX	Increase peak throughput Better handling of TCP flows
	Header coding/capacity	Improve robustness and reduce overheads
	IFG flexibility	Reduce system overhead
	New LPDU size	Increase transmission efficiency
	Multi Level Coding (MLC)	Reduce complexity at the receiver side
DLL	Throughput stability	Increase QoS
Management	Improved management framework	Integration with managed Managed Home Networks

Other features are still under investigation by ITU-T Q18/15

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CONCLUSION

G.HN2 SUMMARY: CHALLENGES

- G.hn2 provides a new, more adapted PHY to new applications.
- G.hn2 provides a roadmap for the improvement of powerline devices in the coming months and years.
- A lot of work has already been done but, standardization process still open (Suggestions welcome!)
- Many challenges still exist (to be addressed in the coming months)
  - Reduce latency
  - Increase minimum guaranteed xput
  - Increase peak xput
  - Robustness of the link
  - Predictability of the link
  - … And many others