New ITU-T Recommendations for Smart Grid in-home and access communications

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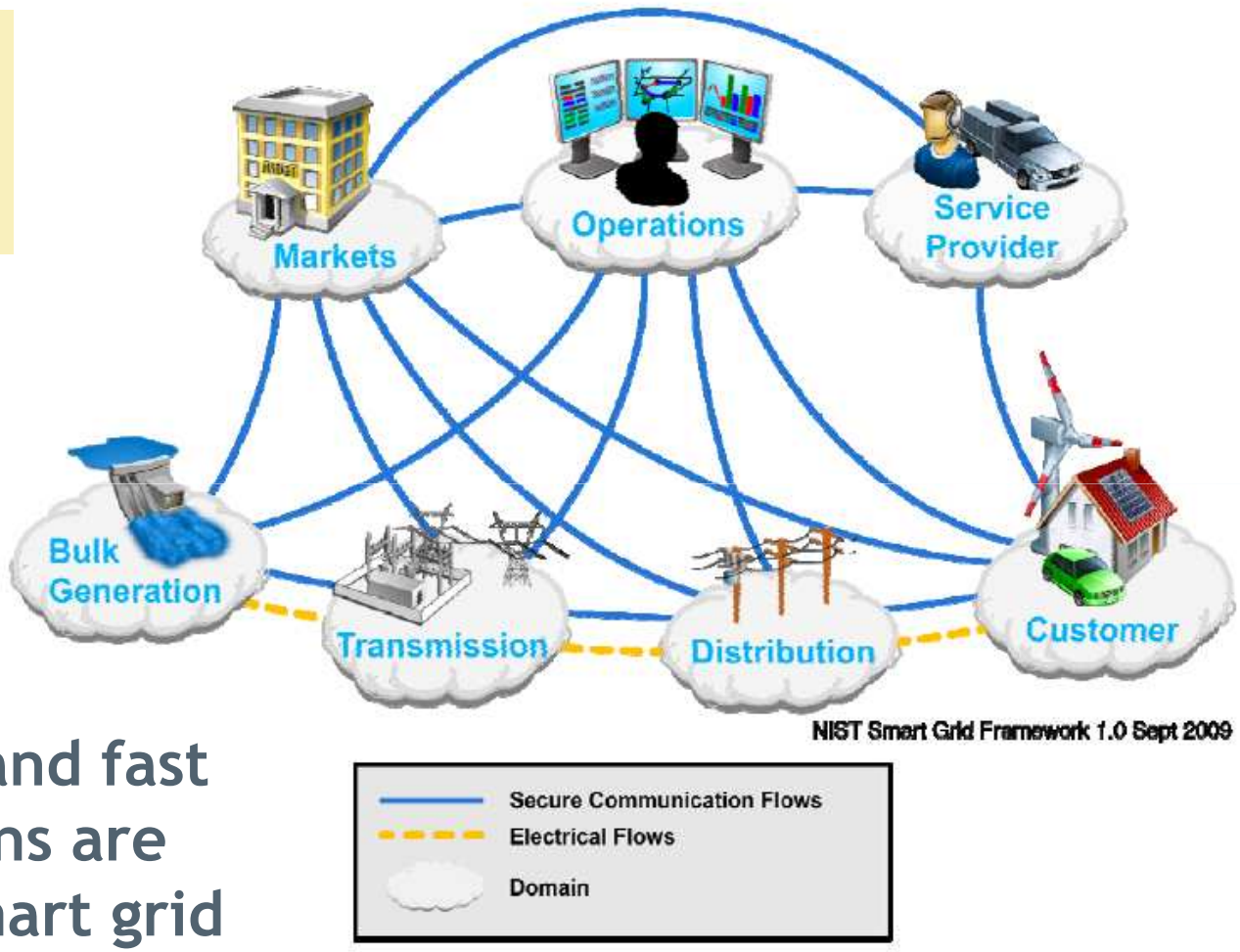
Smart grid domains and communications

Smart Grid intelligently integrates actions of all entities associated with an electricity network

Dynamic monitoring, control, management, self-healing, are key components of the Smart Grid.



NIST Smart Grid Framework 1.0 Sept 2009

Reliable, secure, and fast telecommunications are the core of the Smart grid

Interoperable PLC technologies in Smart Grid

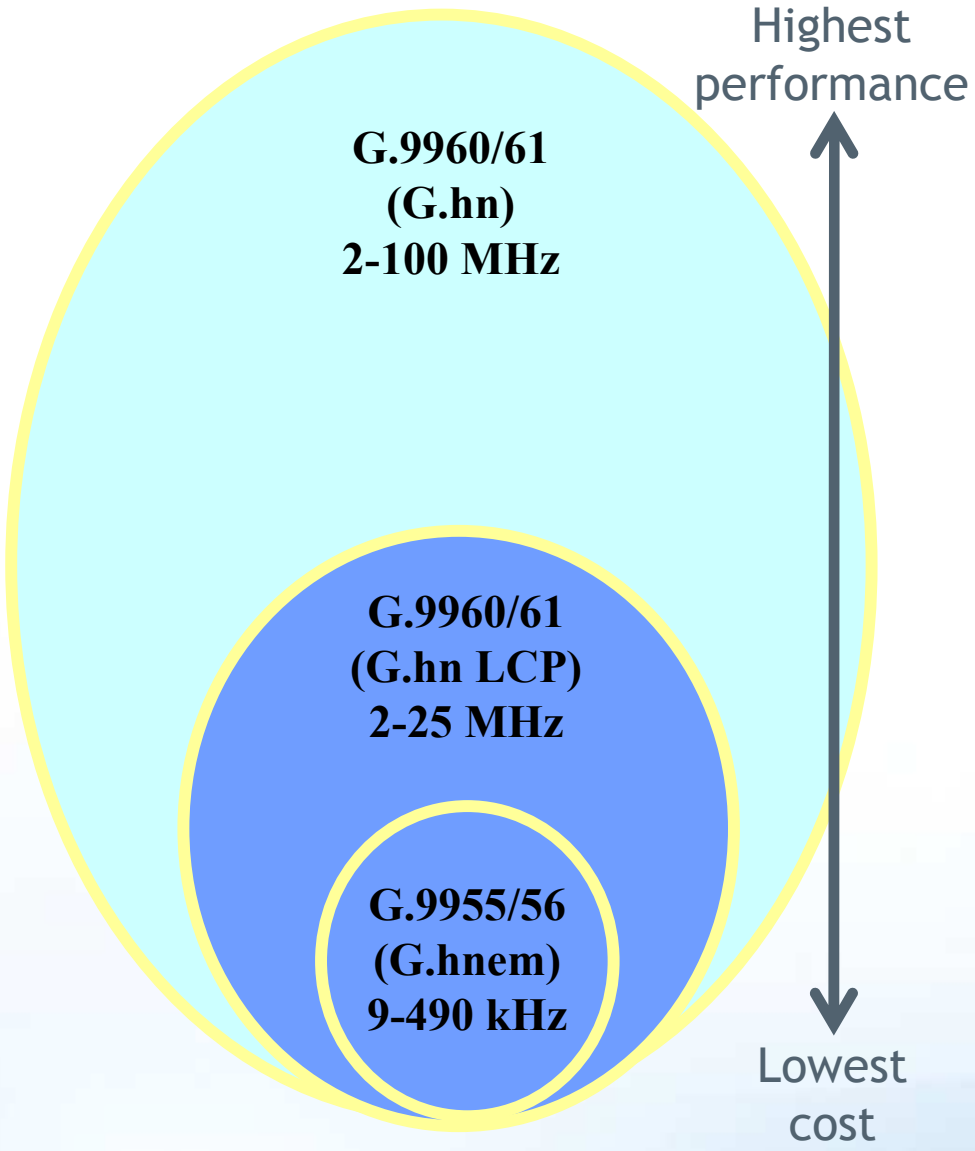
- PLC is substantial for Smart Grid since the communication medium is reliable, for free, and serves all main applications:
  - Control, monitoring, protection, Advanced Metering Infrastructure (AMI), In-home energy management (EM, DR), and Plug-in electrical vehicle (PEV)
- Unfortunately, the continuing existence of multiple incompatible PLC standards (see backup slides), confuses the industry and results in expensive, unreliable solutions
- **In 2009 NIST established Smart Grid Interoperability Panel (SGIP) to provide the industry with interoperable standards**
- **ITU believes that a single international standard is the best guarantee for interoperability between multiple vendors**

  In 2010, ITU-T established a Smart Grid Focus Group (SGFG) with the main goal to develop, in cooperation with ISO/IEC, a set of Recommendations on next generation communication technologies for Smart Grid

ITU-T: Next Generation PLC standards for Smart Grid

- Formed in 1865, now a U.N. agency, recognized by WTO;
- Includes 191 member states and a number of sector members (private entities)
- Delivers open international standards for telecommunications

ITU-T family of next generation PLC standards



ITU-T developed a family of PLC networking technologies based on OFDM modulation and advanced coding methods

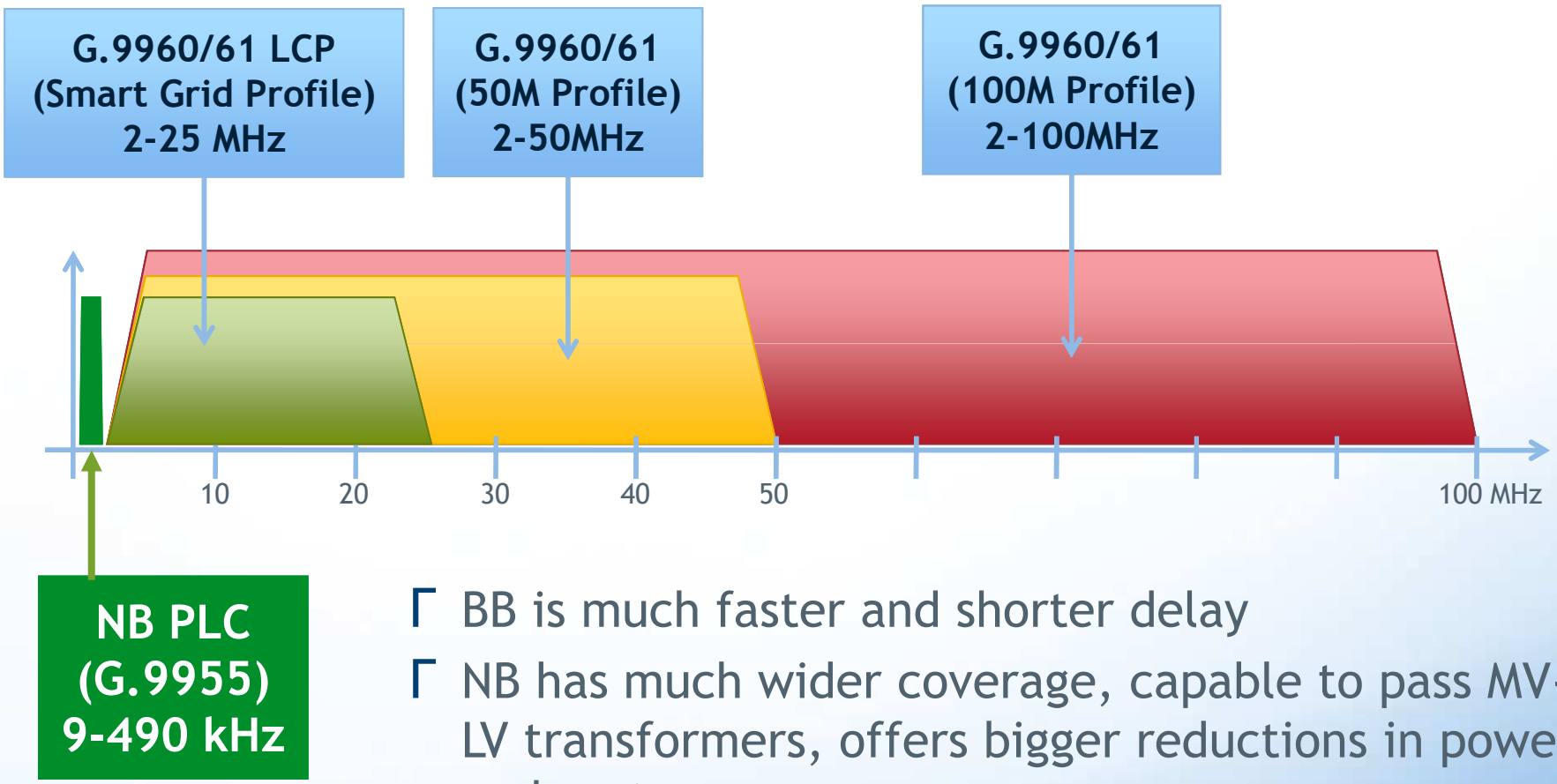
G.9960/61:
Multiple media, bit rates to of hundreds Mb/s to 1Gb/s;
BB networking & entertainment

G.9960/61 LCP - Smart Grid BB:
Reduced bit rate (5-20 Mb/s), complexity, and power consumption

G.9955/56 - Smart Grid NB PLC:
Bit rates up to 1 Mb/s, high robustness; very low complexity and power consumption

BB and NB PLC for Smart Grid

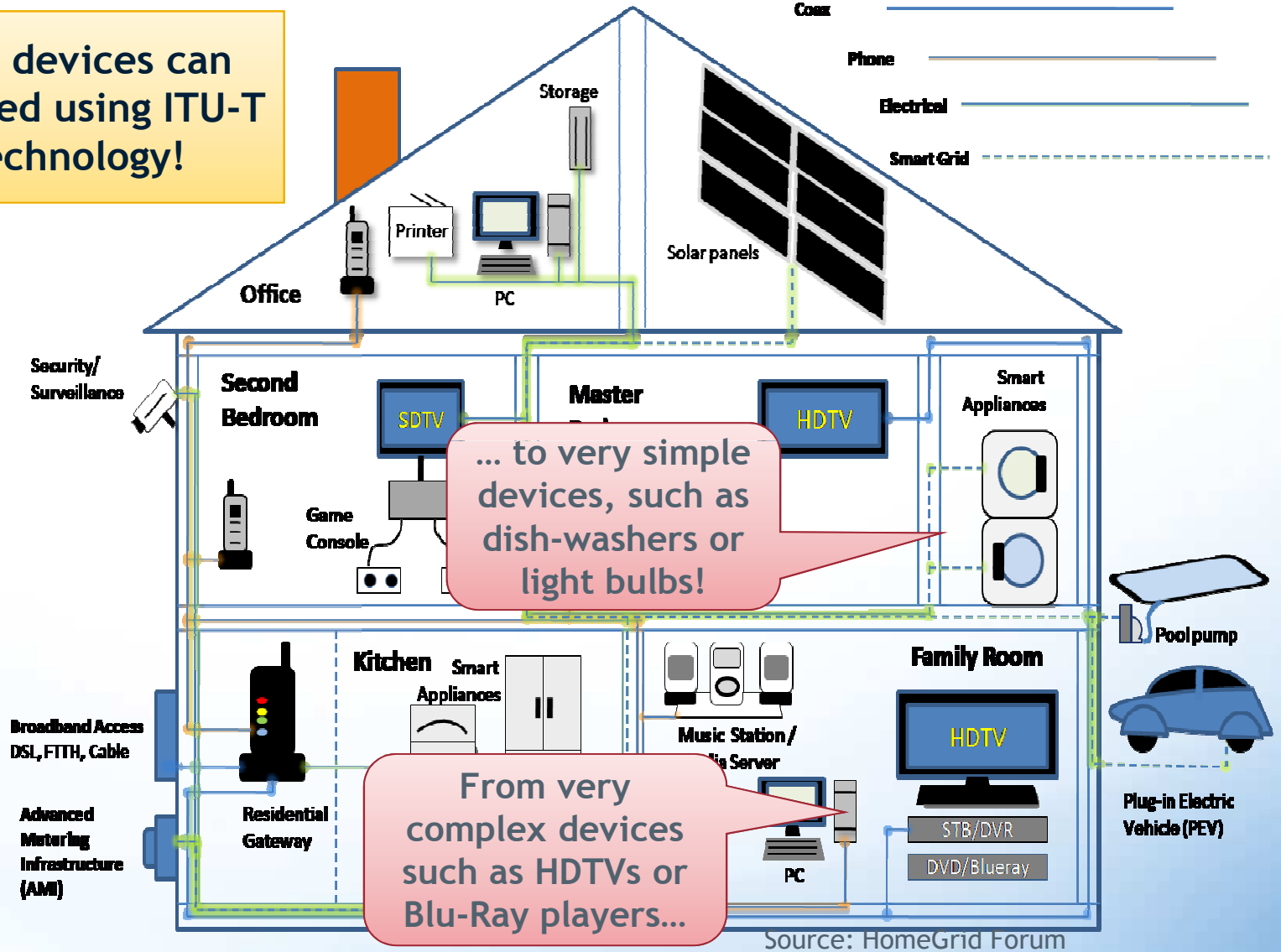
- NB and BB PLC use different spectrum - no impact on each other!



- BB is much faster and shorter delay
- NB has much wider coverage, capable to pass MV-LV transformers, offers bigger reductions in power and cost

ITU-T BB/NB PLC can fully support future digital home

All these devices can be managed using ITU-T PLC technology!



Source: HomeGrid Forum

Main requirements for Smart Grid devices

Functional Area	Smart Grid Home Networks
Data Rate	Low (<1 Mb/s)
Reliability	Very High!
Quality of Service	Best Effort with bounded delay, low latency
Power Consumption	Very Low!
Range	AMI range for access applications Single home (plus detached buildings) or MDU
Security	High!
Typical Network Size	AMI: 10 (rural) and 400 (urban) In-home: 30+ devices
EMC compliance	Complies with different regional regulations
Complexity (Cost)	Low!

Interoperability and “plug & play” operation are the key requirements

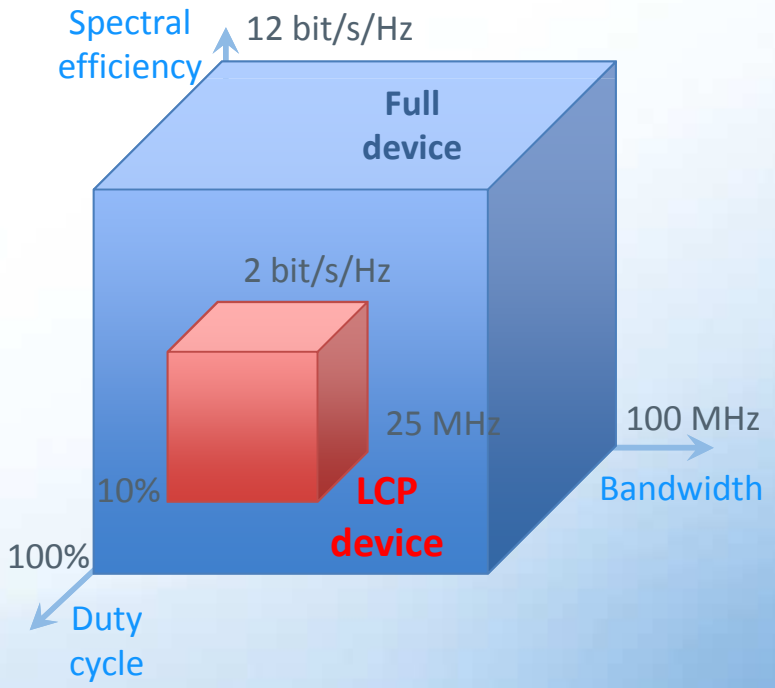
BB PLC for Smart Grid (ITU-T G.9960/61)

- Started April 2006, **approved June 2010**
- Supported by multiple silicon vendors: Intel, Lantiq, Panasonic, Sigma Designs, Marvell, Metanoia, Xingtera
- Extension of G.9960/61 including MIMO is under development

G.9960/61 for Smart Grid - LCP

- The G.9960/61 Low Complexity Profile (LCP) operates 2-25MHz over all in-home wired media (powerline, coax, phoneline) and interoperable with other G.9960 profiles (50 MHz, 100 MHz)
- Main features:
  - low complexity (QPSK only, r=1/2, low throughput, etc.)
  - low power consumption

  Scaled with overall 1:240 ratio for throughput/complexity/power
- The LCP still maintains
  - low latency
  - full mesh networking
  - advanced security (AES-128, CCMP)
  - coexistence with neighboring BBs
  - flexible and dynamic PSD control
  - support of multiple L3 protocols
  - diagnostic mode
  - other common features of G.9960/61



G.9960/61 LCP – Smart Grid applications

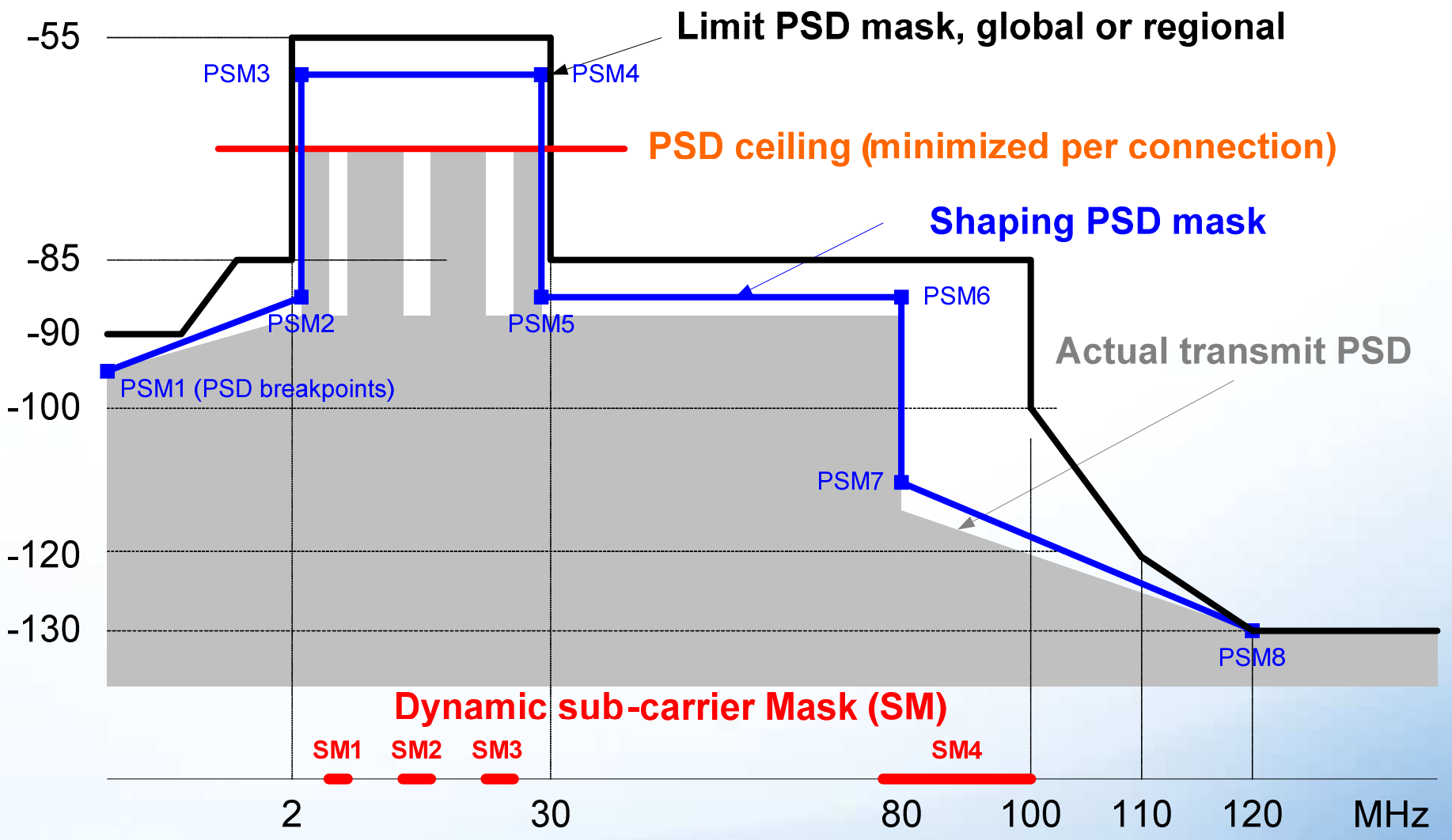
- **Targets all typical Smart Grid applications:**
  - AMI
  - Smart appliances
  - Energy management devices (e.g., PST, EMS)
  - PEV charging
  - also, wide-band home automation applications

- **Two efficient, dynamic power saving modes:**
  - long-term (multiple AC cycles) scheduled inactivity
  - short-term (inside each AC cycle) scheduled inactivity

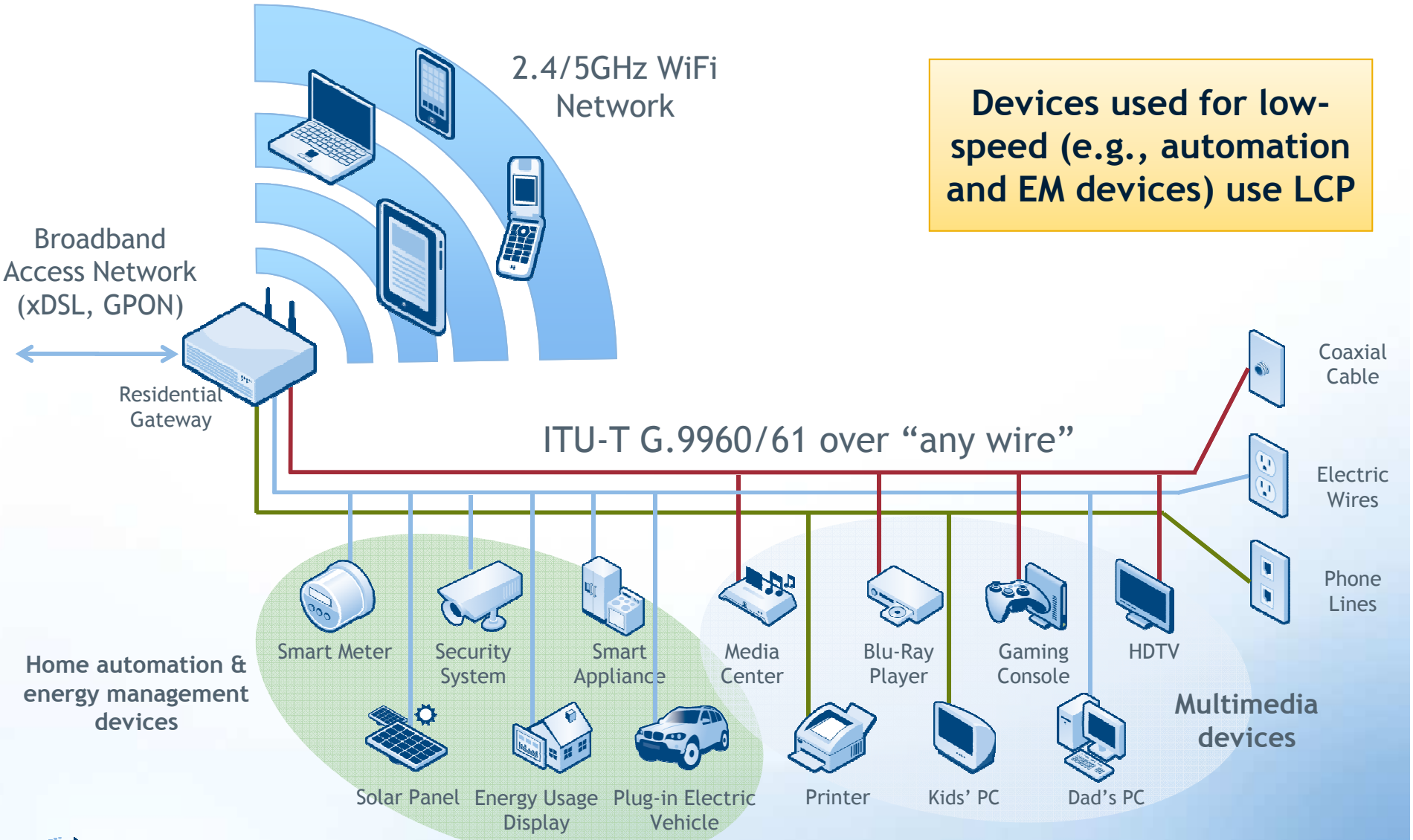
  Smart Grid devices wake up synchronously for a short period of MAC cycle, in pre-scheduled way, providing minimum impact on broadband services and very low power consumption.

- **More details of Smart grid applications of G.9960/61**:
  "Applications of ITU-T G.9960 transceivers for Smart Grid":
  http://www.itu.int/dms_pub/itu-t/opb/tut/T-TUT-HOME-2010-MSW-E.doc

EMC compliance – flexible PSD shaping and dynamic notching



Multi-medium support - more devices and more flexibility



Devices used for low-speed (e.g., automation and EM devices) use LCP

NB PLC for Smart Grid (ITU-T G.9955/56)

- Started January 2010, **consented for approval Feb 2011**
- Supported by multiple silicon vendors: Maxim, Lantiq, Texas Instruments, Yitran, Marvell, Metanoia, Sigma Designs
- Advanced medium access procedures, relaying, and coexistence mechanisms are under development

G.9955/56 - Background

- G.9955/56 (**9-490 kHz**) is developed to be the next generation NB PLC standard for Smart Grid (AMI, EM, PEV)
- Based on legacy OFDM NB PLC (mainly, G3), with **the main goal to improve coverage, throughput, reliability (impulse noise and channel variation immunity), maintaining low complexity and low power consumption**
- Regional requirements and EMC regulations are addressed by multiple bandplans (CENELEC, FCC-1, FCC-2, ARIB) and Annexes
- Developed by ITU-T SG15 Q4 in cooperation with ISO/IEC, SAE (automotive); compliant with IEEE P1901.2 via legacy Annexes

Detailed structure and status of G.9955/56

- **G.9955 (PHY) and G.9956 (DLL) contains:**
  - Main body, defines the next generation NB PLC
  - Legacy annexes, documenting G3 and PRIME
  - Regional annexes (regional bandplans and EMC issues)
  - Annex for automotive applications
  - Annex defining support for different Layer 3 protocols (G.9956)
- **Status – Entered the final stage of approval**
  - G.9955: Assigned for TAP - only editorial changes are allowed
  - G.9956: Assigned for AAP - currently sent for Last Call Comments
- Some pre-standard products were already demonstrated, standard products expected shortly after standard approval (Q4 2011).

Main goal of G.9955 - Improved performance and robustness

#	Feature	Legacy OFDM solutions	G.9955/56
1	Higher noise immunity	Differential modulation	Coherent modulation
2		Up to 6 repetitions	Up to 12 repetitions
3		Interleaving sensitive to frequency erasures	Improved interleaving, not sensitive
4		Preamble detection based on phase switch (unreliable)	Detection method robust to erasures Added a robust preamble mode
5		Fixed header duration	Robust header mode, for very high-noise scenarios
6		Single FCC bandplan	Multiple FCC bandplans improves transformer crossing
7			Modulation parameters are optimized per bandplan

Other advantages of G.9955/56

#	Feature	Legacy OFDM solutions	G.9955/56
8	Higher bit rate	BPSK, QPSK, and 8PSK	Up to 16 QAM, wider band
9		Code rate only 1/2	Uses also higher code rate 2/3
10	Multiple bandplans	CENELEC A only or one FCC sub-band	CENELEC A, B, CD, and three FCC bandplans (to address better MV-LV transformers)
12	Media access, prioritization	Simple CSMA with 2 priorities (simple Low/High)	Flexible and dynamic prioritization (in progress)
13	Acknowledgement protocol	Short MPDU, no selective ACK, single type of ACK	Long MPDU, both selective and non-selective ACK
14	Upper layers protocols	IPv6 only	Multiple L3 protocols, including IPv4 and Ethernet
15		No support for L3 routing (RPL)	Supports L3 routing protocols
16	Low power	Limited means to manage	Four low power modes required

G.9955 – Main Technical Parameters

Parameter	Value	Notes
Transmission method	OFDM	To ensure operation in frequency-selective channels
Bandplans	CENELEC (3-148.5 kHz) FCC (9-490 kHz)	CENELEC A (32-95 kHz), CENELEC B (95-125 kHz) CENELEC CD (125-1408 kHz) FCC (32-490 kHz), FCC-1 (32-150 kHz), FCC-2 (150-490kHz)
Per-carrier modulation	BPSK, QPSK, 16QAM	16-QAM provides 2x the data rate of legacy technologies. Coherent modulation improves SNR by 2.5-5dB
Forward Error Correction	Concatenated Reed-Solomon + Convolutional + Interleaver	Core rates 1/2 and 2/3 and up to 12 repetitions provide robustness against noise and erasures in frequency/time
Data rate	Up to 1 Mb/s over FCC band	Lower data rate when using narrower bandplans (data rate proportional to spectrum use)
Media access method	Prioritized CSMA/CA	Flexible prioritization and access rules. Full mesh networking at L2 as an option
Network protocol	Multiple, IPv6 is a default	Can support additional Layer 3 protocols, and supports full mesh networking at Layer 3
Security	AEC-128, CCM (NIST)	CCMP (also used by 802.11n, 802.15.4, G.9961)
Legacy Support	G3, PRIME over CENELEC A G3 over FCC (Automotive)	Support for legacy technologies is described in Annexes included in the standard
Automotive Support	Special Annex for automotive applications	Operates over main and pilot wires, improved noise immunity, reduced crosstalk
Smart Appliances	NIST PAP-15 requirements	Complies to all those relevant for PHY and DLL

Business and marketing support – HomeGrid Forum

- Main goal – ensure interoperability, promote and certify products based on G.9960/61 and G.9955/56
- Worldwide industry representation
  - Service providers
  - Consumer electronics
  - Personal computing
  - Silicon suppliers and IP companies
  - Certification labs
- Liaison agreements with key industry groups
  - DLNA, CEPCA, UPA, HomePNA, EPRI ZigBee, Z-Wave, DRSG, CABA, U-SNAP

Conclusions

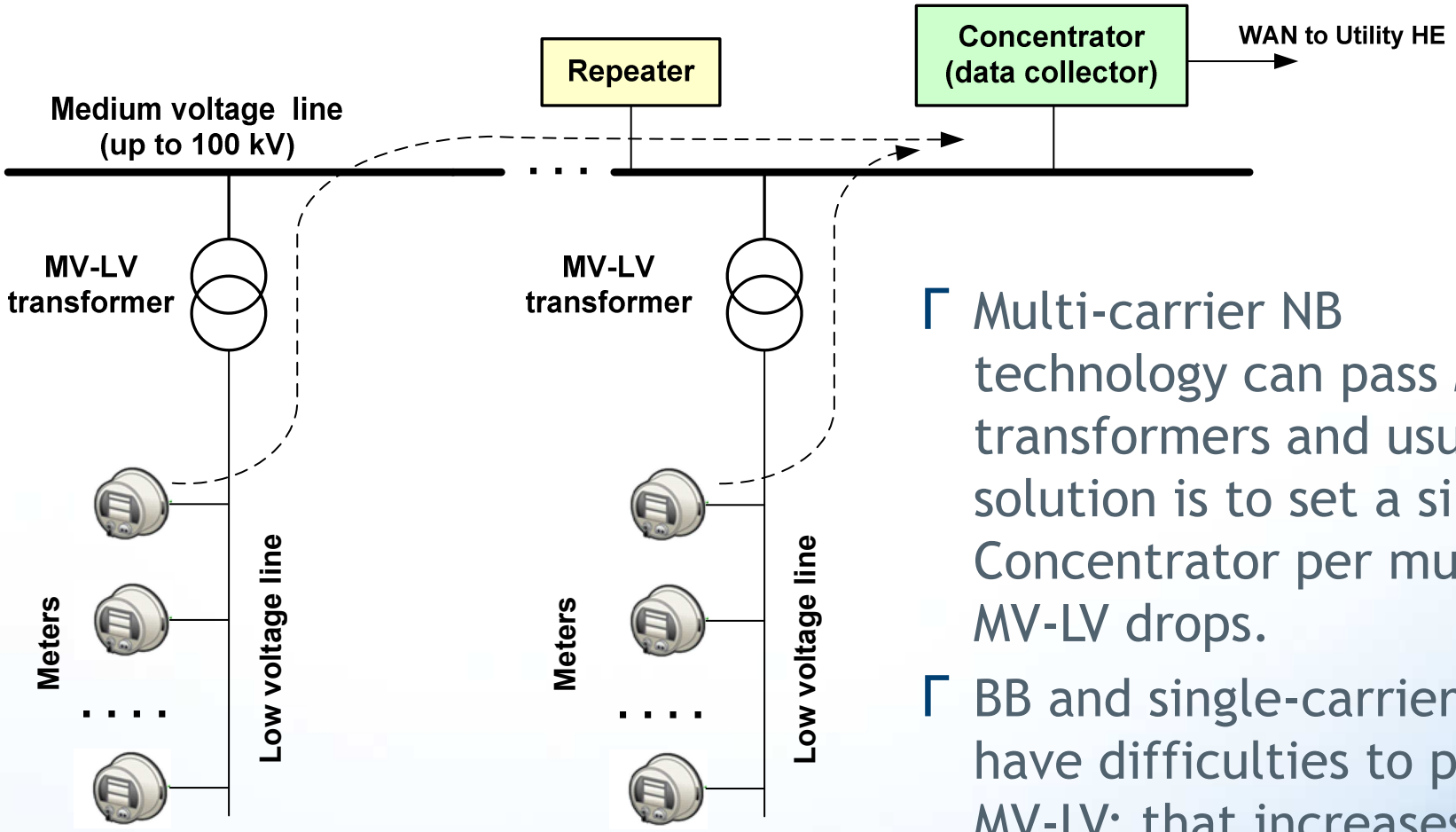
- ITU-T is the major SDO for telecom standards, now develops worldwide telecommunication standards for Smart Grid:
  - For utility access - support of AMI (AMM/AMR)
  - For in-home energy management (DR, smart appliances, etc.)
  - For automotive – support of EVSE and PEV
- ITU-T approved G.9960/61 in June 2010 – Smart Grid high-speed communications technology that coexists with in-home broadband
- ITU-T consented for approval G.9955/56 in Feb 2011- Smart Grid narrow band communications technology that coexists with legacy FSK deployments and intended to coexist with IEEE P1901.2
- Both ITU-T Recommendations got multi-vendor support

Support of ITU-T Recommendations brings interoperable next generation standards for Smart Grid communications, applicable worldwide

THANKS for your time!

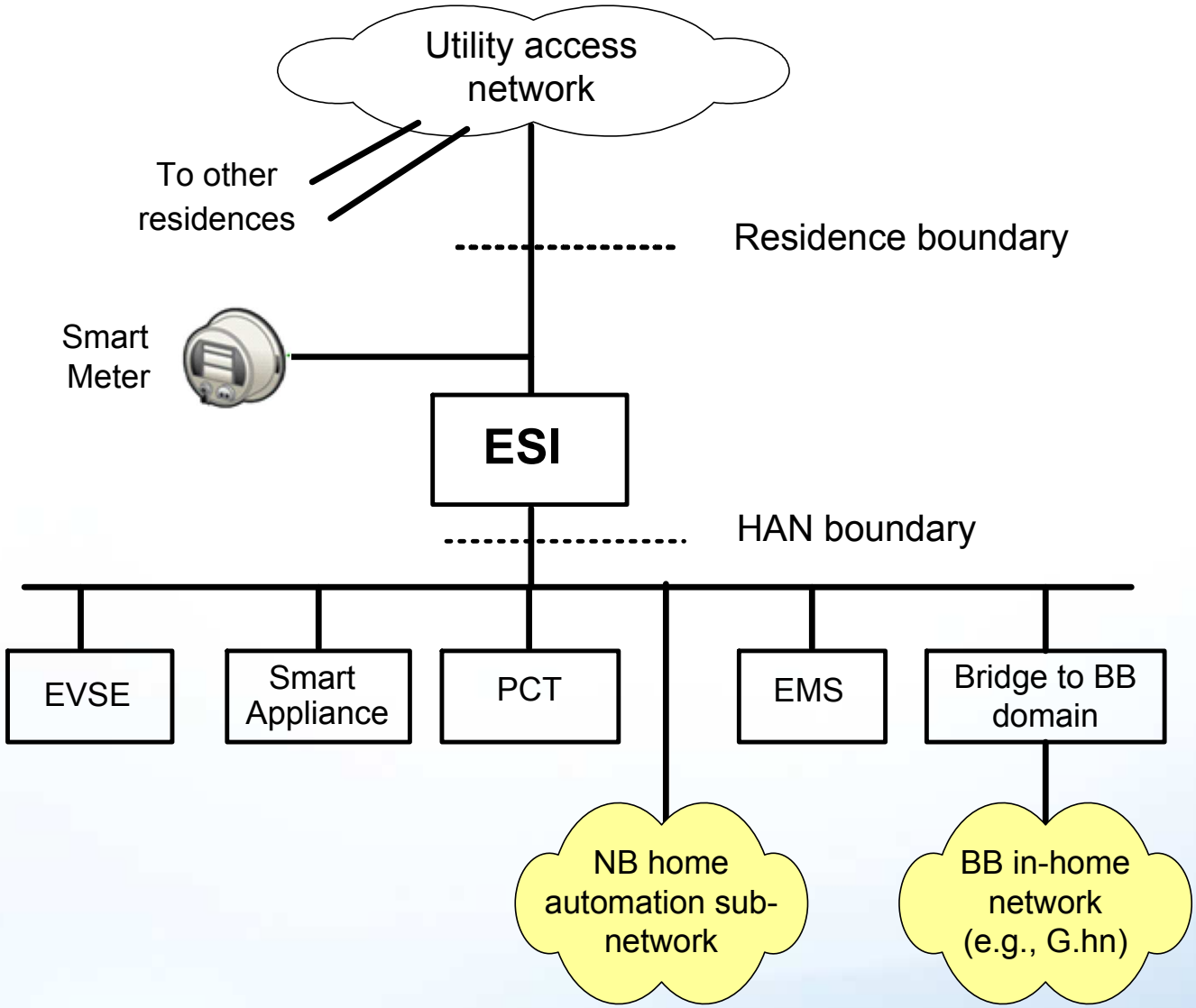
Backup slides

NB PLC solution for AMI



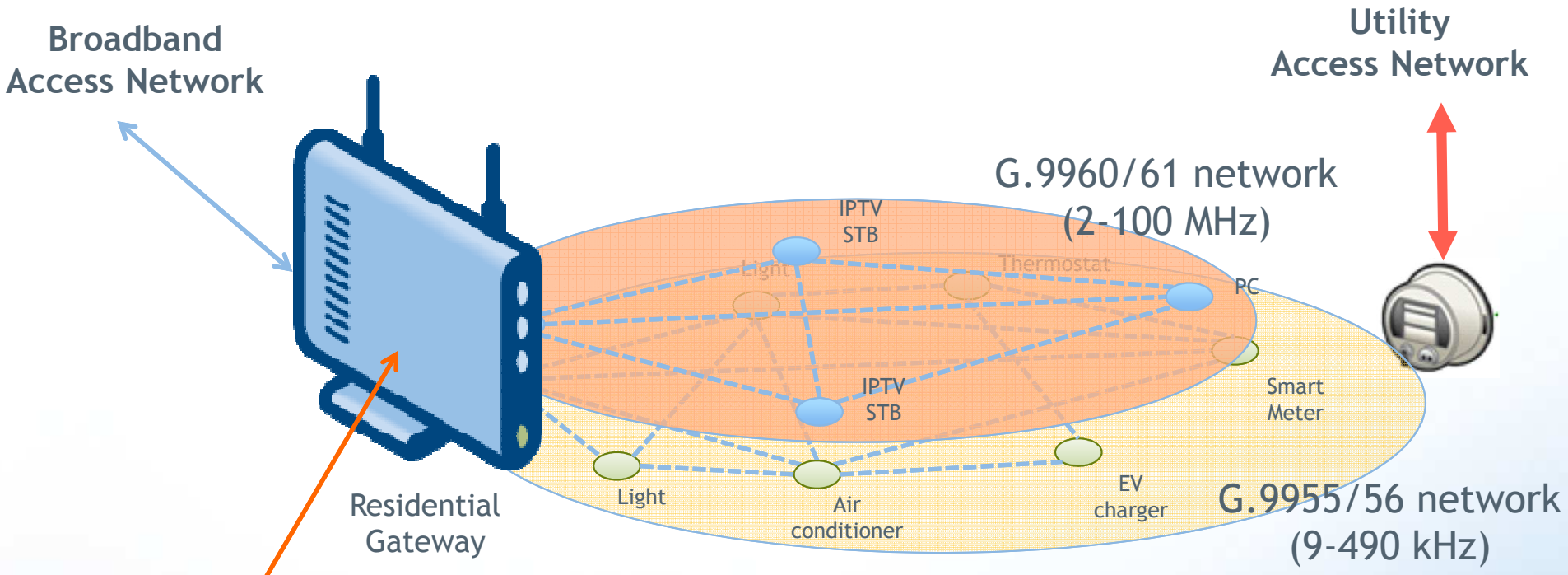
- Multi-carrier NB technology can pass MV-LV transformers and usual solution is to set a single Concentrator per multiple MV-LV drops.
- BB and single-carrier NB have difficulties to pass MV-LV; that increases system cost and complicates management

NB PLC solution for in-home EM



- Connects all Smart Grid devices inside the home
- Bridges all HAN devices to the Utilities via Energy Service Interface (ESI)
- Bridges all HAN devices to BB network (via the residential gateway)

Joint operation of G.9960/61 and G.9955/56

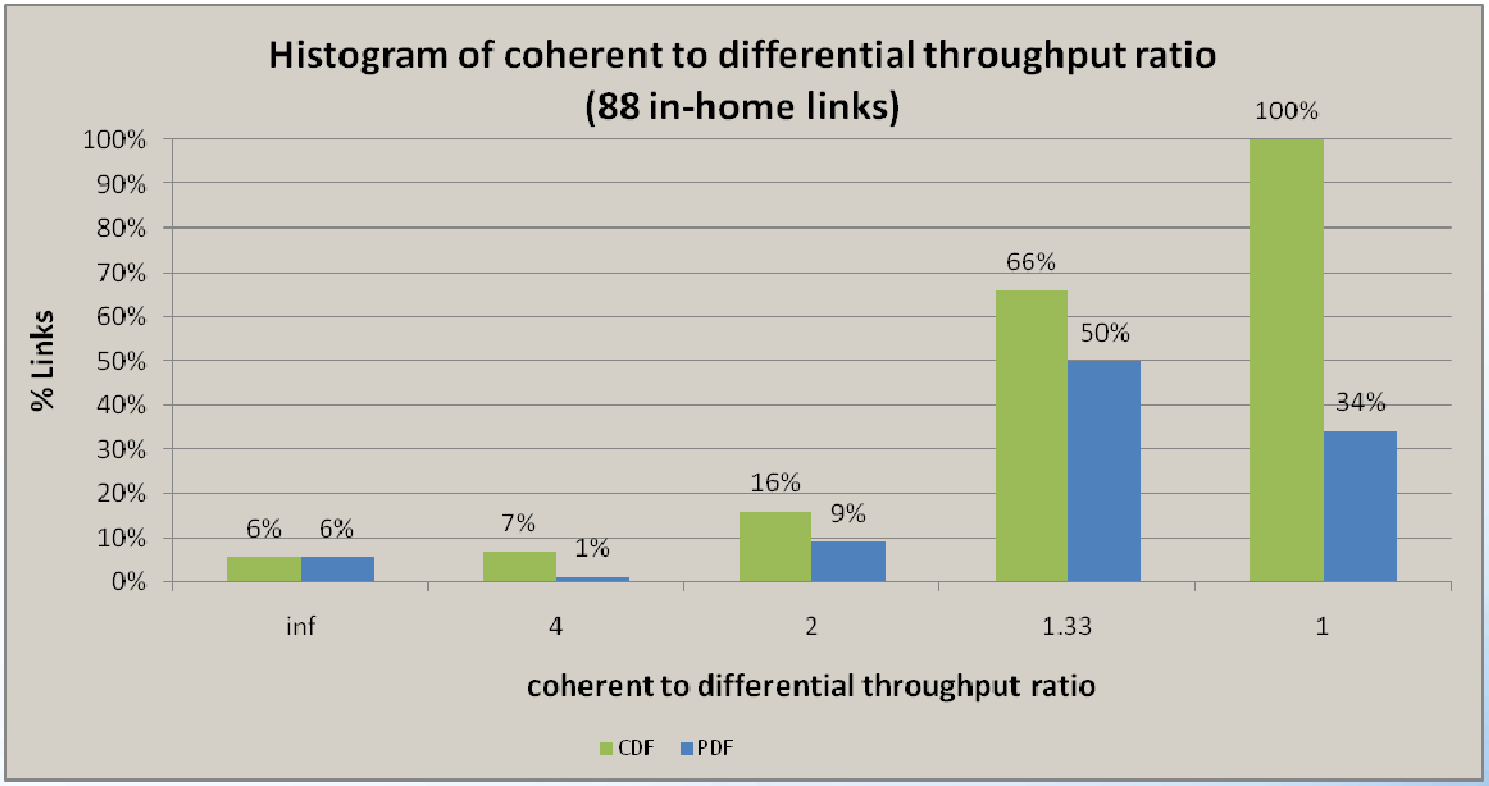


Residential Gateway bridges G.9960/61 and G.9955/56 networks using common IP protocol

G.9960/61 and G.9955/56 use different spectrum, and thus can operate simultaneously over the same wiring without impacting each other's performance

G.9955 - Reported field tests

- First field tests reports on pre-standard G.hnem were submitted to ITU-T SG15 by **Yitran** in 2010. The tests were mainly to check advantages of coherent modulation in real environment



ITU Focus Group on Smart Grid

- The Focus Group (SG FG) was established to:
  - identify potential impacts on standards development;
  - investigate future ITU-T study items and related actions;
  - familiarize SGs with emerging attributes of smart grid
- The Focus Group collaborates with worldwide smart grid communities (e.g., research institutes, forums, academia) including other SDOs and consortia.
  - The group has liaised with the major stakeholder organizations to collect information on the current status of their work.
- The FG consists of 3 working groups:
  - WG1 on Use cases
  - WG2 on Requirements
  - WG3 on Architecture

BB-PLC specifications (band above 2 MHz)

Organisation type	Organisation(s)	Technology Name	Frequency Bands	Description	Spec
International SDO	ITU	ITU G.hn (G.9960/G.9961)	2-100MHz		X
Industry Specification	IEEE	IEEE 1901	2-50MHz	- Similar to HomePlug AV, HD-PLC, ISP with add. features. - The use of 30-50MHz is optional.	X
Industry Specification	TIA	TIA-1113	4.5-25MHz	Similar to HomePlug 1.0.	X
International SDO	ISO/IEC	ISO/IEC 12139-1	2-30MHz	Korean PLC standard	X
Proprietary Specification	Fujian	GPLC	?	?	
Industry Specification	HD-PLC Alliance	HD-PLC	2-30MHz	Wavelet-based Panasonic PLC specification	
Proprietary Specification	Atheros	HomePlug 1.0 Turbo	?	HomePlug 1.0 variant. Not sure it is formally endorsed by HomePlug Alliance.	
Proprietary Specification	Arkados	HomePlug 1.0 Plus	?	HomePlug 1.0 variant. Not sure it is formally endorsed by HomePlug Alliance.	
Industry Specification	HomePlug	HomePlug AV	2-30MHz		X
Proprietary Specification	Atheros	HomePlug AV Extended	2-75MHz	HomePlug AV variant. Not sure it is formally endorsed by HomePlug Alliance, or part of HomePlug AV 2.0.	
Proprietary Specification	Gigle	HomePlug AV Mediaxtream	2-30MHz 50-300MHz	HomePlug AV variant. Not sure it is formally endorsed by HomePlug Alliance, or part of HomePlug AV 2.0.	
Industry Specification	HomePlug	HomePlug GreenPHY	2-30MHz	This is a stripped down version of HomePlug AV.	X
Proprietary Specification	Phonex	Neverwire	?	?	
Proprietary Specification	Spidcom	Spidcom C200	?	?	
Industry Specification	UPA Alliance	UPA 200/400	?	?	
Proprietary Specification	Watteco	WPC LRWBS	2-4MHz	This technology targets low-rate home automation, energy management, etc.	

G.9960/61 is the only international standard that serves multiple media and provides interoperable lower complexity solution optimized for Smart Grid

NB-PLC specifications (band below 2 MHz)

Organization Type	Organization(s)	Technology Name	Frequency Bands	Usage	Modulation Methods	Signal Level Plan
International SDO	ITU-T SG-15/T4	G.hnem (Draft)	CENELEC A/B/C/D FCC 9 to 490 kHz	Adjustable number of Sub Carriers Multiple FCC bandplans	OFDM	EN 50065-1, FCC Part 15
International SDO	ISO/IEC, ANSI, LonMark	LonWorks, ISO/IEC 14908-3, ANSI 709.2	A (86 KHz & 75.453 kHz 125 kHz - 140 kHz F_c=131.579 kHz CENELEC A, B, C	dual carrier A (86 kHz & 75.453 kHz) C (131.579 kHz & 86.232 kHz)	BPSK / NRZ	EN 50065-1, FCC Part 15
International SDO	ISO/IEC, BS	KNX, ISO/IEC 14543-3-5, EN 50090	PL110 (95 kHz - 125 kHz F_c=110 kHz) PL132 (125 kHz - 140 kHz F_c=132.5 kHz)	A(60 kHz, 66 kHz, 72 kHz, 76 kHz, 82.05 kHz, 86 kHz) B 110 kHz C 132.5 kHz	S-FSK / NRZ	EN 50065-1
International SDO	IEC TC57 WG09	IEC 61334-3-1, IEC 61334-5-1, IEC 61334-5-2, IEC 61334-4-32	CENELEC A 20 kHz - 95 kHz	10 kHz tone seperations	S-FSK	EN 50065-1
National SDO **(withdrawn)**	ANSI, CEA, EIA	CEBus, CEA-600.31	100-400 kHz	Swept Frequency Carrier, Semantic sweep states covering entire band	PWM / NRZ	FCC Part 15
IEEE	IEEE - P1901.2	P1901.2 (Draft)	CENELEC A (G3 PLC, PRIME) FCC 159kHz to 490 kHz	CENELEC A band and FCC band; adjustable number of sub-carriers	OFDM	EN 50065-1, FCC Part 15
Industry Specificaton	INSTEON Alliance	INSTEON	131.65 kHz	single carrier	BPSK	FCC Part 15
Industry Specification	HomePlug Alliance	HomePlug C&C	FCC (120-400 kHz), CENELEC A,B	Spread Spectrum FCC 120-400Khz CA 20-80Khz, CB 95-125Khz	Single carrier, spread spectrum DCSK6, DCSK4	EN 50065-1, FCC Part 15
Industry Specificaton	PRIME Alliance uSyscom, ADD, STM, TI	PRIME	CENELEC A (~42 kHz - ~89 kHz), Capable up to 500 kHz	97 subcarriers, 488 Hz spacing	OFDM / DBPSK, DQPSK, D8PSK	EN 50065-1, FCC Part 15
Industry Specificaton (publically available)	Maxim, ERDF, Texas Instruments	G3 PLC	35.9-90.6 kHz / CENELEC-A field tested (capable up to 180 kHz)	36 carriers / CENELEC-A (capable up to 128)	OFDM / DBPSK, DQPSK	EN 50065-1, FCC Part 15
Proprietary Specification	PCS	UPB	4-40 kHz		PPM	FCC Part 15
Proprietary Specification	*Pico Electronics*	X10	120 kHz	single carrier	OOK	FCC Part 15
Proprietary Specification	ACT	A10	120 kHz	single carrier	OOK	FCC Part 15
Proprietary Specification	Maxim	G3 Lite MAX2990 (FCC band extension being developed)	10KHz - 490KHz Cenelec-FCC	Adjustable number of Sub Carriers	OFDM	EN 50065-1
Proprietary Specification	Phillips	Phillips TDA5051A	F_c within 95 kHz - 145 kHz (132.5 kHz typical)	single carrier	ASK	FCC Part 15
Proprietary Specification	Ariane Controls	PLM-1	50-500 kHz, 262 kHz expected	single carrier	FSK / NRZ	FCC Part 15
Proprietary Specification	ENEL	SITRED	CENELEC A 20 kHz - 95 kHz	10 kHz tone seperations	S-FSK	EN 50065-1
Proprietary Specificaton	Yitran/Rensas	C&C Turbo (fully comply with HomePlug C&C)	FCC (120-400 kHz), CENELEC A,B	Spread Spectrum FCC 120-400Khz CA 20-80Khz, CB 95-125Khz	Single Carrier, spread spectrum, DCSK Turbo, DCSK6, DCSK4	EN 50065-1, FCC Part 15

Technology Comparison, NB PLC

Technology	G3	Prime	i-bus EIB KNX	dsi	G.hnem
Accumulated Datarate (Mbps)	34 kbps	130 Kbps	2400 bps	1000 bps (?)	1 Mb/s
Typ. Loop Length	~3 km	~3 km	<100m	<100m	~3-4 km
Layer 2 Transp.	IPv6 (Ethernet needs convergence)	"IPv4, IEC 62056, IEC 61334-4-32	--	--	IPv6, IpV4, Ethernet, .. (L3 protocol flexible)
Max. Signal BW	3-95 kHz 150-490 kHz	3-95 kHz	3-148 kHz	3-148 kHz	32-490 kHz
Modulation	OFDM 128 (Differential)	OFDM 96 (Differential)	FSK	-	OFDM-128/256 (coherent)
Sub-carrier spacing	1.56/4.68 kHz	488 Hz	--	--	1.56/3.12 KHz
Bands	CSMA/CA	CSMA/CA + TDM	--	--	CSMA/CA + TDM
Coding	RS plus Convolutional	Convolutional	--	--	RS plus Convolutional
Bus Structure	Bus	Bus	Bus	Bus	Bus
Security	AES-128	AES128	None	None	AES128
Topology	1 domain controller & n participants	1 domain controller & n participants	1 service node & n clients	1 service node & n clients	1 domain controller & n participants, inter-domain controller

G.9955 and IEEE P1901.2

- IEEE started P1901.2 about 5 month after G.9955, with mainly the same goals for the standard as G.9955. There was an almost 9-month effort to merge operation of both groups, although it didn't happen

- The groups are currently working independently:
  - P1901.2 decided to standardize G3 as the main body, document the legacy technologies (same as ITU-T does) and potentially specify an optional mode that will use coherent modulation (similar to G.9955)
  - ITU-T keeps alignment with P1901.2 via legacy annexes; A method of coexistence and interoperability with P1901.2 is under intensive discussion