Making the Smart Grid Real

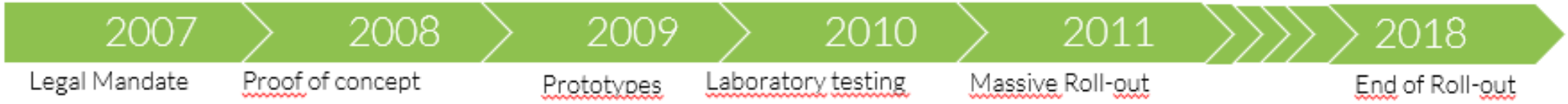
PRIME Evolution towards 1.4

Index

- PRIME PLC and SmartGrids
- PRIME 1.4 PHY Layer Evolution
- PRIME 1.4 MAC Layer Evolution
- Starting the deployment of PRIME 1.4

PRIME PLC and SmartGrids

First deployment of PRIME 1.3.6



- In 2010 Spain starts its first deployment of PRIME 1.3.6 SmartMeters
- The initial deployment concludes in 2018 with 15 million meters deployed
- The deployment is widely successful:
  - 100% AMI SmartMeters remotely managed
  - 100% Digital Secondary Substations
  - More Automatization in the Grid

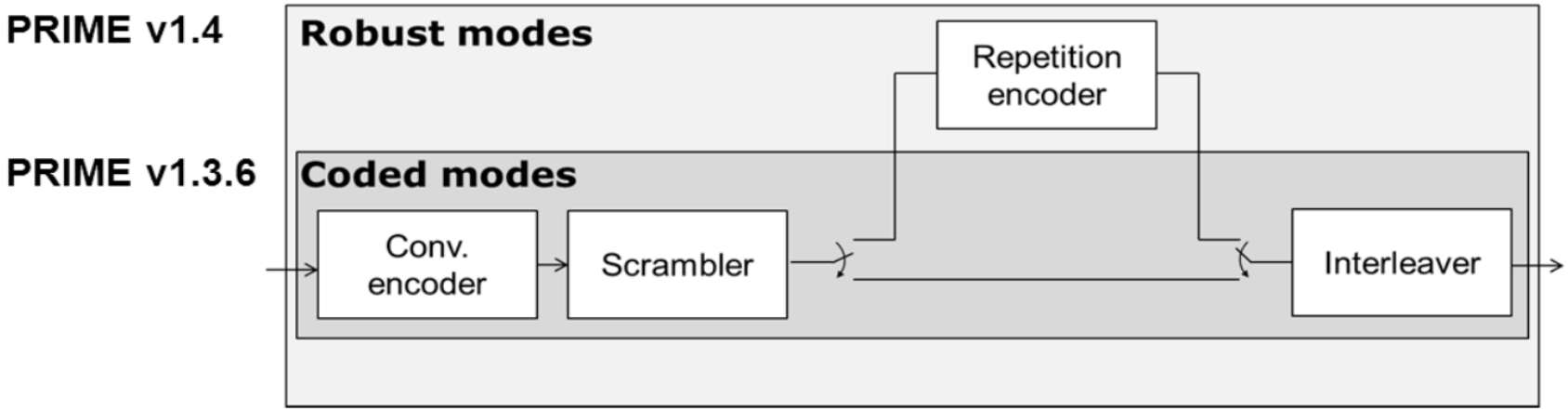
PRIME PLC and SmartGrids

Moving towards PRIME 1.4

- In 2025 begins the renewal of meters due to a 15-year useful life limit and new regulatory milestones
- During this time there has been an evolution of the PRIME Technology to its PRIME 1.4 version
- This new version includes significant improvements that address previous limitations of the technology:
  - PHY Layer improvements
  - MAC Layer improvements
- This new PRIME 1.4 version presents new opportunities as well as challenges and impacts the future deployment

PRIME 1.4 PHY Layer Evolution

Robust modes – Overview



- Robust modes: 4 times repetition of the same signal, Preamble, header and payload
- Improve against notching and impulsive noise. More reliable communications

PRIME 1.4 PHY Layer Evolution

Robust modes – Preamble extension

- Repeat the original preamble 4 times (sign inversion)
- From 2.048ms chirp to 8.192ms
- Noise rejection: Robustness
- More precise synchronization (key for OFDM)

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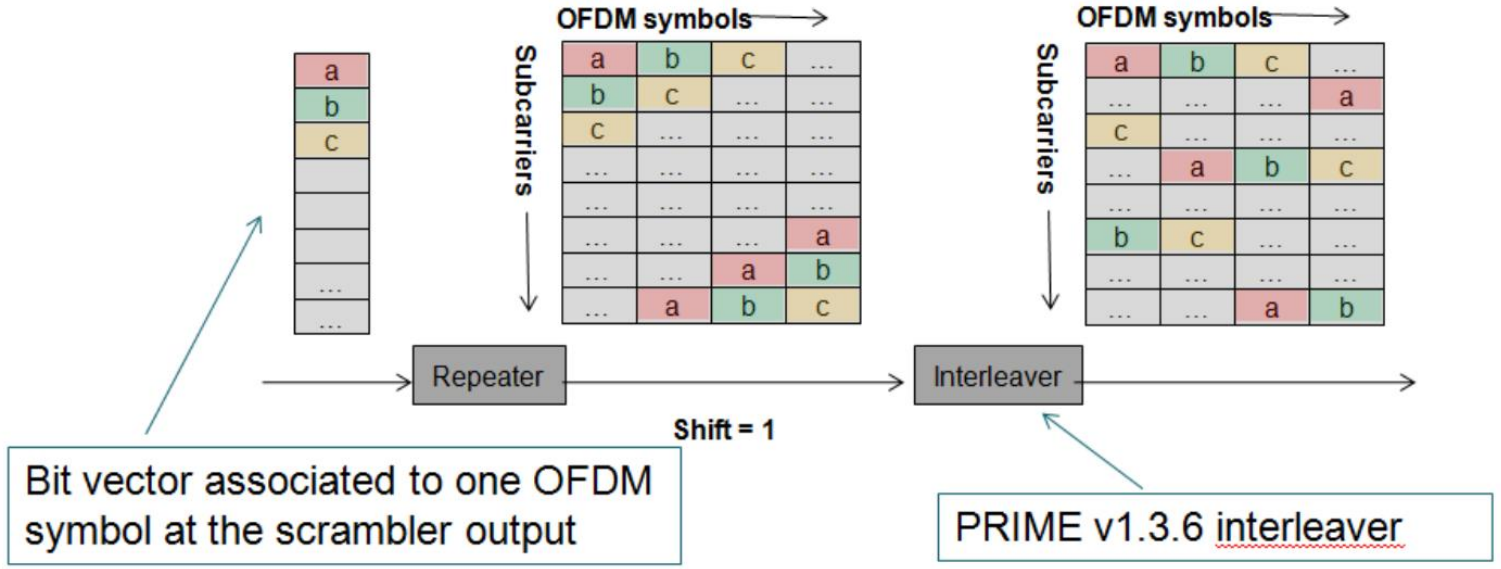
PRIME 1.4 PHY Layer Evolution

Robust modes – Repetition block

- Applies to header and payload
- 1 symbol to 4
- Adds temporal diversity (information is spread in time – Impulsive noise)
- Adds frequency diversity (same information transmitted at different carrier frequencies - Notching)

PRIME 1.4 PHY Layer Evolution

Robust modes – Repetition block (2)

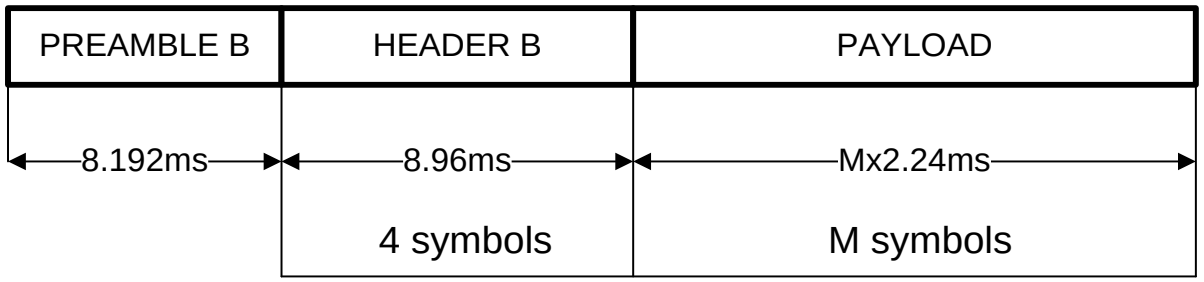


- There is a cyclic shift in frequency for each repetition
- Interleaver distributes the information across all subcarriers
- DBPSK and DQPSK modulation (Higher bit density)

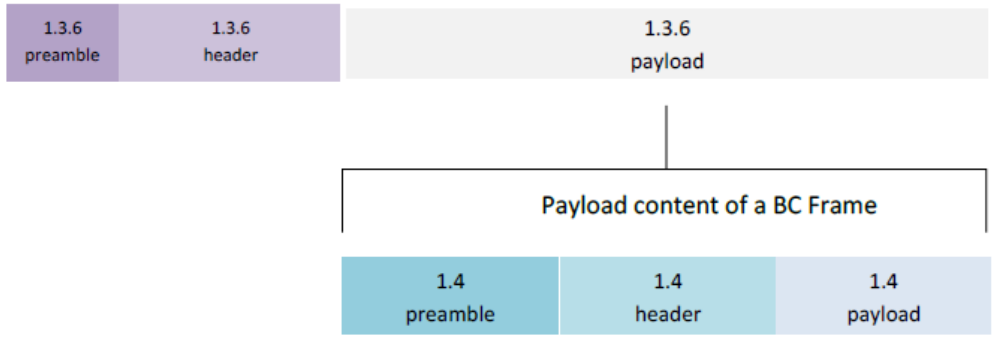
PRIME 1.4 PHY Layer Evolution

Robust modes – Type B and BC Frames

- Type B Frame: Header is optimized. Only one symbol before repetition (4 in 1.4 vs 2 in 1.3.6).



- Type BC Frame: Mechanism to avoid collisions in a mixed network (1.4 and 1.3.6 devices)



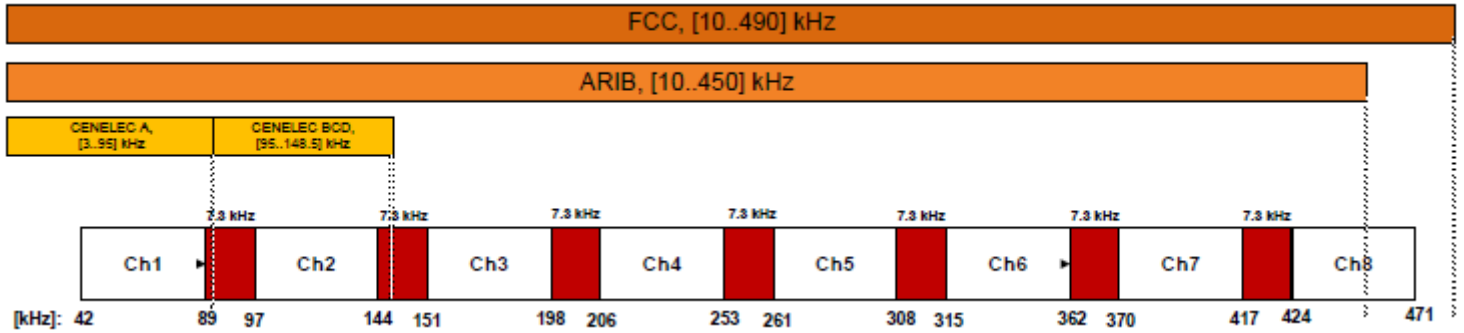
PRIME 1.4 PHY Layer Evolution

Robust modes – Simulation results

- Prime technical group simulations
- Gaussian white noise, up to 4dB
- Notched channels, up to 6dB
- Impulsive noise, up to 14.5dB

PRIME 1.4 PHY Layer Evolution

The FCC Band - Overview



- PRIME v1.4 supports both, CENELEC A band and 7 additional channels in the frequency range<500 kHz
- All channels are equivalent to channel 1, 96 data subcarriers
- Channel 2 is not used in Spain

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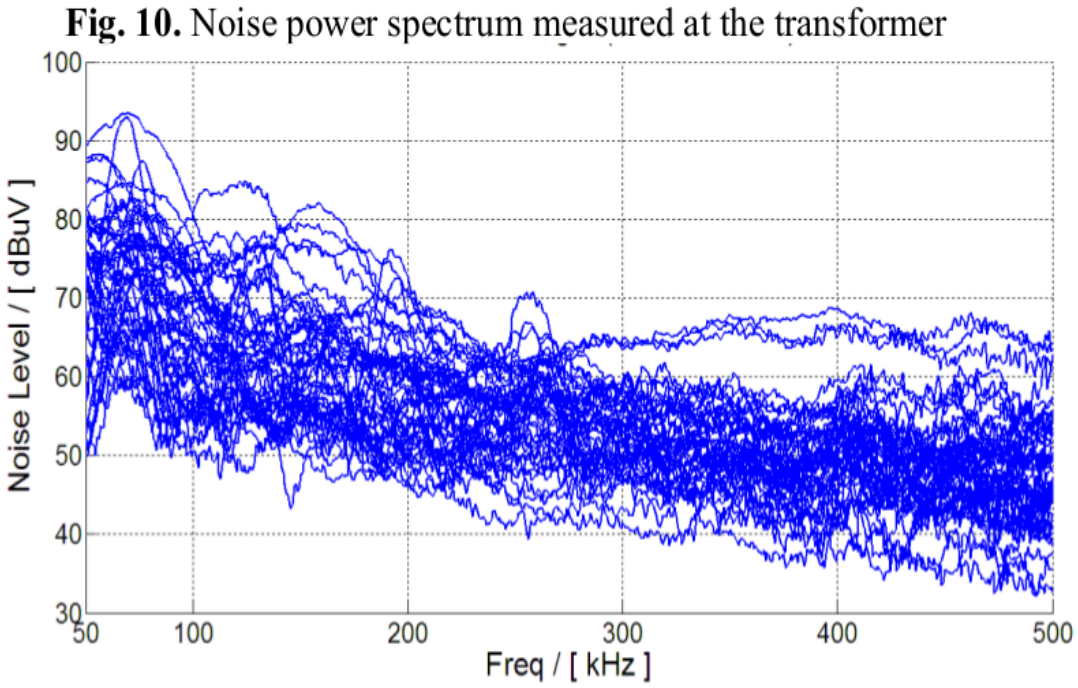
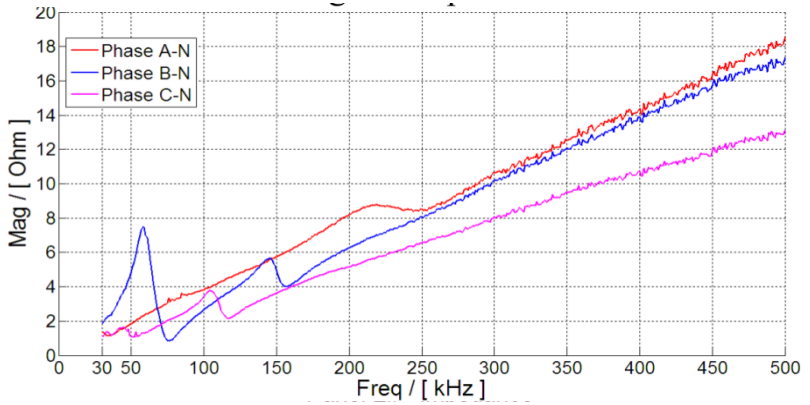
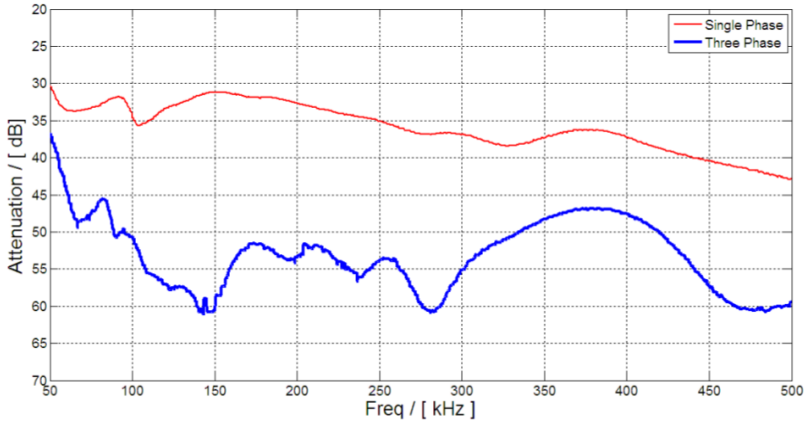
PRIME 1.4 PHY Layer Evolution

The FCC Band – Line parameters

- Saturated spectrum vs Less congested. Better communications
- Higher frequencies: Reduce noise, increase impedance and attenuation







PRIME 1.4 MAC Layer Evolution

Traffic optimizations

- PRIME 1.3.6
  - Control traffic to maintain the subnet is >60% of the total traffic
  - Once a switch starts switching multicast for a group it never stops
- PRIME 1.4 fixes some of these issues:
  - Multicast switching management has been moved to the BN so only switches that actually have to repeat traffic repeat it
  - Time values of several concepts has been increased all through the Spec
    - Examples: Alive times, commands, promotion needs...

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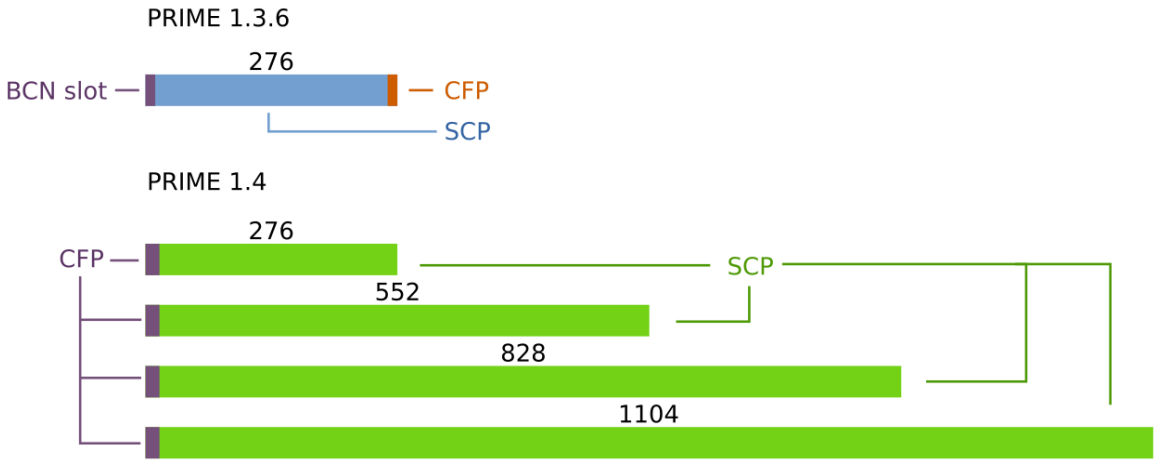
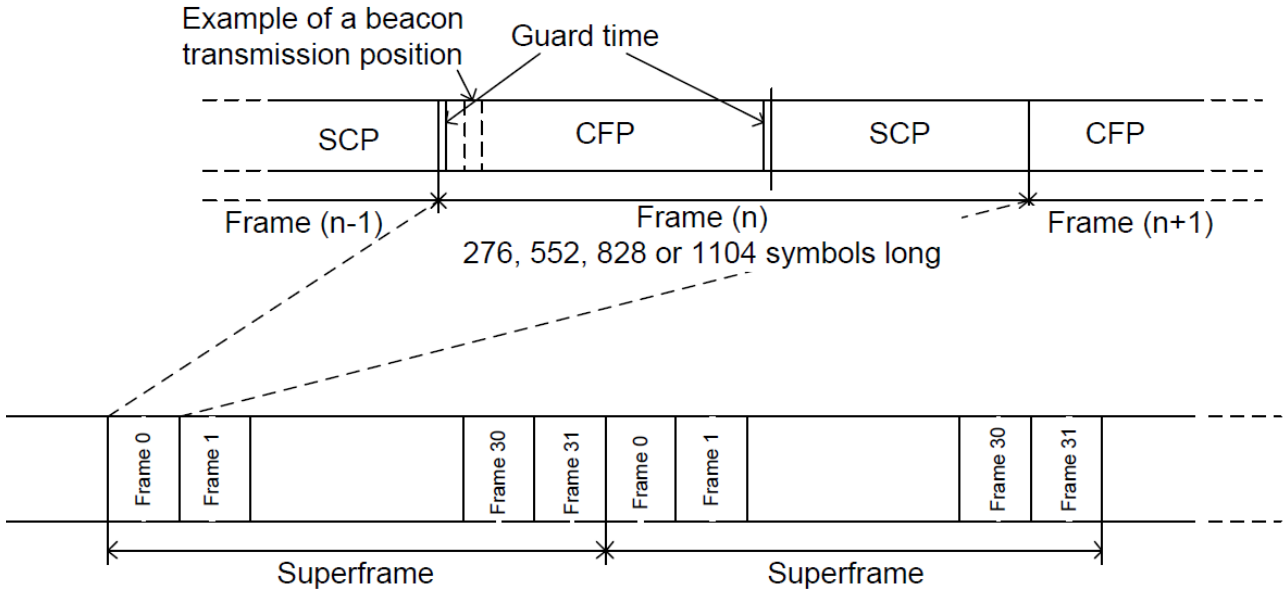
PRIME 1.4 MAC Layer Evolution
Frame control

- Frame has been adapted and now have configurable larger lengths
  - 276 symbols → 276, 552, 828 or 1104 symbols
  - Less CFP/BCN slot → less sync points → better CSMA/CA





PRIME 1.4 MAC Layer Evolution

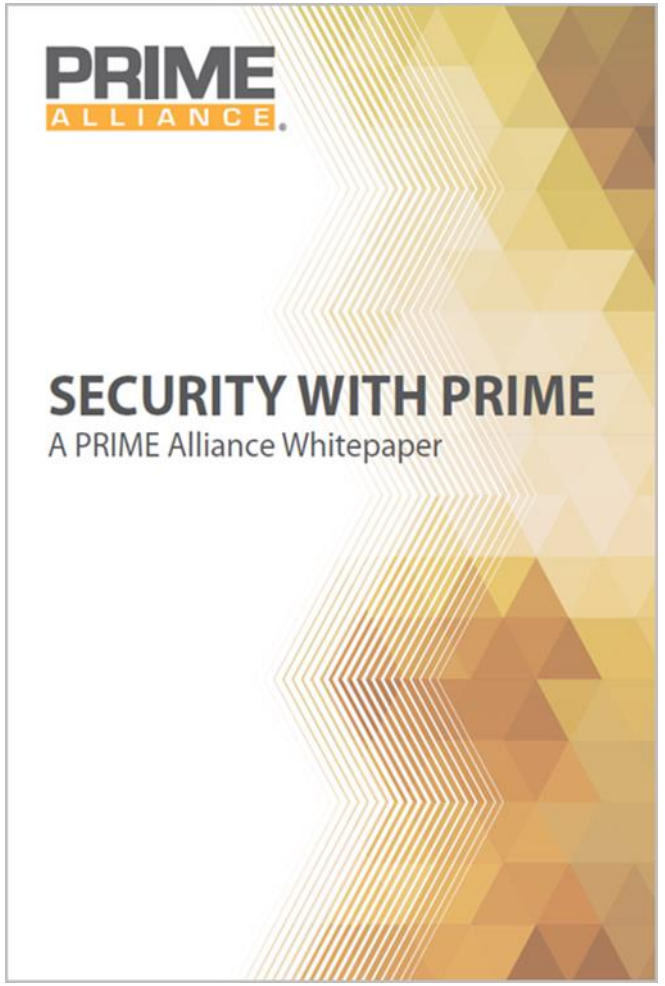
Robust Management

- PRIME 1.3.6 has no specific mechanism to determine which modulation to use in point-to-point communications
- PRIME 1.4 introduces a Robust communication management:
  - Each generic MAC PDU has RM information
    - Allows having updated information with no bandwidth loss
    - Clear information on which encoding could be used with the last received power
  - New Alive mechanism is used to manage robustness
    - Packet level RM has an issue: going from non robust to robust mode is not well handled
    - Alive makes sure the robustness will be increased if needed because it now includes a link level ACK

PRIME 1.4 MAC Layer Evolution

Security

- PRIME 1.3.6 defines security but is incomplete and not working, security relies on upper layers
- PRIME 1.4 security is written from the scratch
  - AES-128-CCM for data
  - KDF AES-CMAC for key derivation
  - 2 secure profiles to choose between higher security or performance
  - Individual keys for traffic with each meter and a subnetwork key known by all nodes
  - Non secure profile is still available



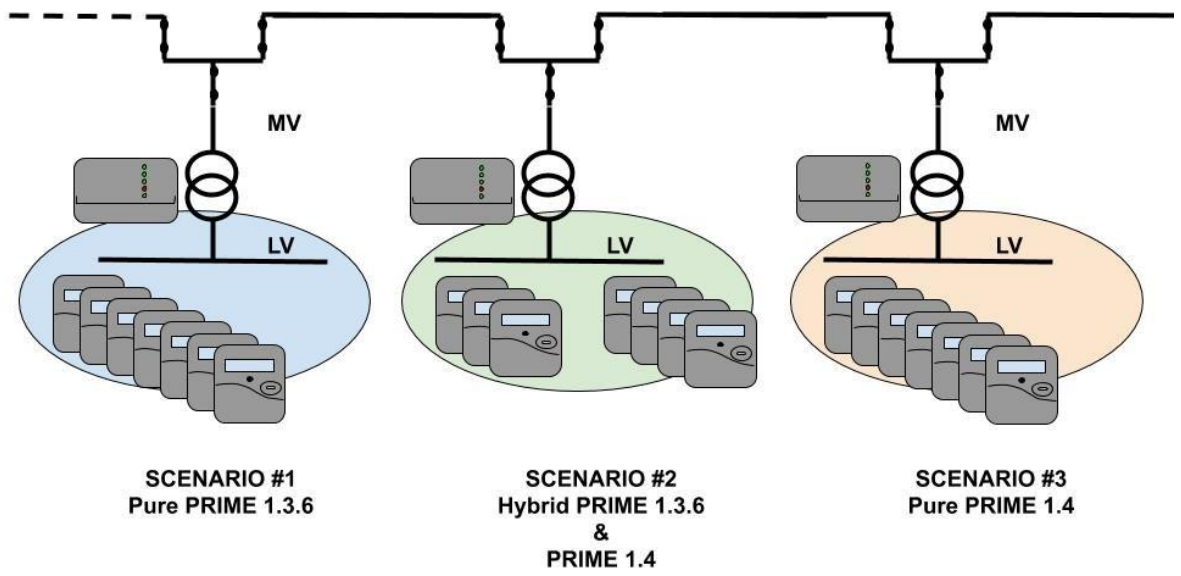
PRIME 1.4 MAC Layer Evolution
Synchronized events

- PRIME 1.4 defines a method to reference temporal events
  - A header with time offset defining an event time
  - Time relative to a specific MAC frame start, frame is synchronized with beacons
  - Frame is selected with frame sequence
  - Switches are aware of this so the information is kept up to date if needed

Name	Length	Description
TREF.SEQ	5 bits	Sequence number of the MAC Frame that is used as reference time of the event to notify.
Reserved	3 bits	Always 0 for this version of the specification. Reserved for future use.
TREF.TIME	32 bits	Signed number in 10s of microseconds between the moment of the event, and the beginning of the frame. Positive for events after the beginning of the MAC frame, and negative for events before the beginning of the MAC frame. 0x80000000 is a special value that means that means that it is an invalid time reference.

Starting the deployment of PRIME 1.4
Migration scenarios

- Three posible scenarios:
  - Pure PRIME 1.3.6 Networks: PRIME 1.3.6 meters are progressively replaced by 1.4 meters in 1.3.6 mode. Once the replacement is completed the whole network is switched to PRIME 1.4.
  - Hybrid PRIME 1.3.6 & PRIME 1.4 Networks: A new PRIME 1.4 network is deployed along the old 1.3.6 network
  - Pure PRIME 1.4 Networks: The old network is replaced at once



Starting the deployment of PRIME 1.4

Hybrid migration challenges

- Issues:
  - Coverage: In PRIME networks, coverage relies on service nodes (meters) acting as switches. Bottlenecks can occur when only one or a few nodes provide coverage to certain areas. If two networks are deployed simultaneously and these critical nodes are part of only one network, the other network may lose coverage in those areas
  - Collision Issues: Two different communication channels are not electrically independent. When a node transmits a PLC signal, it lowers the network impedance across all frequencies, causing significant interference with other nodes transmitting at the same time, even on different frequency bands

- A deployment strategy is needed:
  - Initial bulk replacement is recommended
  - Try to group meters with the same version in service connections
  - Individual meters may need to be switched to address communication issues

Starting the deployment of PRIME 1.4

Conclusions and pilot results

- Meter renewal process over the next 15 years presents both a challenge and an apportunity challenge for utilities
- Utilities have already started piloting the migration towards PRIME 1.4 meters
- The coexistence of two communication networks on a single low-voltage grid can present issues. While it doesn't prevent migration from one version to another over several years, it can impact the meter replacement strategy
- Pilot tests have demonstrated that PRIME 1.4 offers significant improvements in robustness and performance
- Pilot tests also confirm that the coexistence of both networks is feasible and manageable during deployment

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¡Thank you!

PRIME Evolution towards 1.4

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