Asimakis Kokkos, Chair, Technical Specification Group, MulteFire Alliance & Head of Industry Engagement Strategic Initiatives Steering, Nokia

Asimakis Kokkos, serves as the MulteFire Alliance Technical Specification Working Group Chair driving the creation of timely and competitive standards to give MulteFire the necessary technological edge to deliver its objectives. Makis is also heading Industry Engagement Strategic Initiatives Steering at Nokia Mobile Networks, bringing together modern concepts of standardization and innovation.

Makis joined Nokia in 1994,and held leadership positions spanning from global services to research and standardization. He has been a pioneer in getting frequency bands opened in Europe for new license exempt systems and mesh networks, led technology and standardization work in China, and has served as the chairman of Information and Communication Technology in EU China Chamber of Commerce.

Makis received his first degree in Physics and Electronic Automation from University of Athens, Greece, his MSc degree in Digital Communication Systems from Loughborough University, UK and his PhD in modulation and coding from Bangor University, UK. He is a UK Chartered Engineer and Fellow of the Institution of Engineering and Technology.

MulteFire 1.1 and Beyond

Asimakis Kokkos
Chair, Technical Specification Group

MulteFire®: Towards Release 1.1 and Beyond

Agenda

- The MulteFire Vision & Timeline
- MulteFire 1.0 Overview
- MulteFire 1.1 Introduction
- Moving Forward…

What is MulteFire

- Cellular-based technology for standalone operation in unlicensed or shared spectrum
- Delivers LTE-like performance with Wi-Fi-like deployment simplicity
- Allows anyone to create, install and operate their own private or neutral host MulteFire network
    - Ideal for Industrial IoT and Enterprise applications
- Creates new business opportunities that allow existing and new market verticals to deploy and benefit from the LTE technology and ecosystem

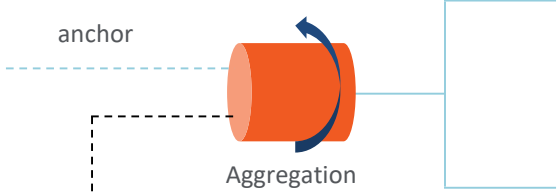
Multiple Technologies will Co-Exist in Unlicensed Spectrum

Licensed Spectrum

Exclusive Use

Unlicensed Spectrum

Shared Use



LTE-U / LAA[1]

Targeting mobile operators using LTE in unlicensed spectrum for new small cell deployments

LWA[2] / LWIP[3]

Targeting mobile operators leveraging existing carrier Wi-Fi deployments

MulteFire

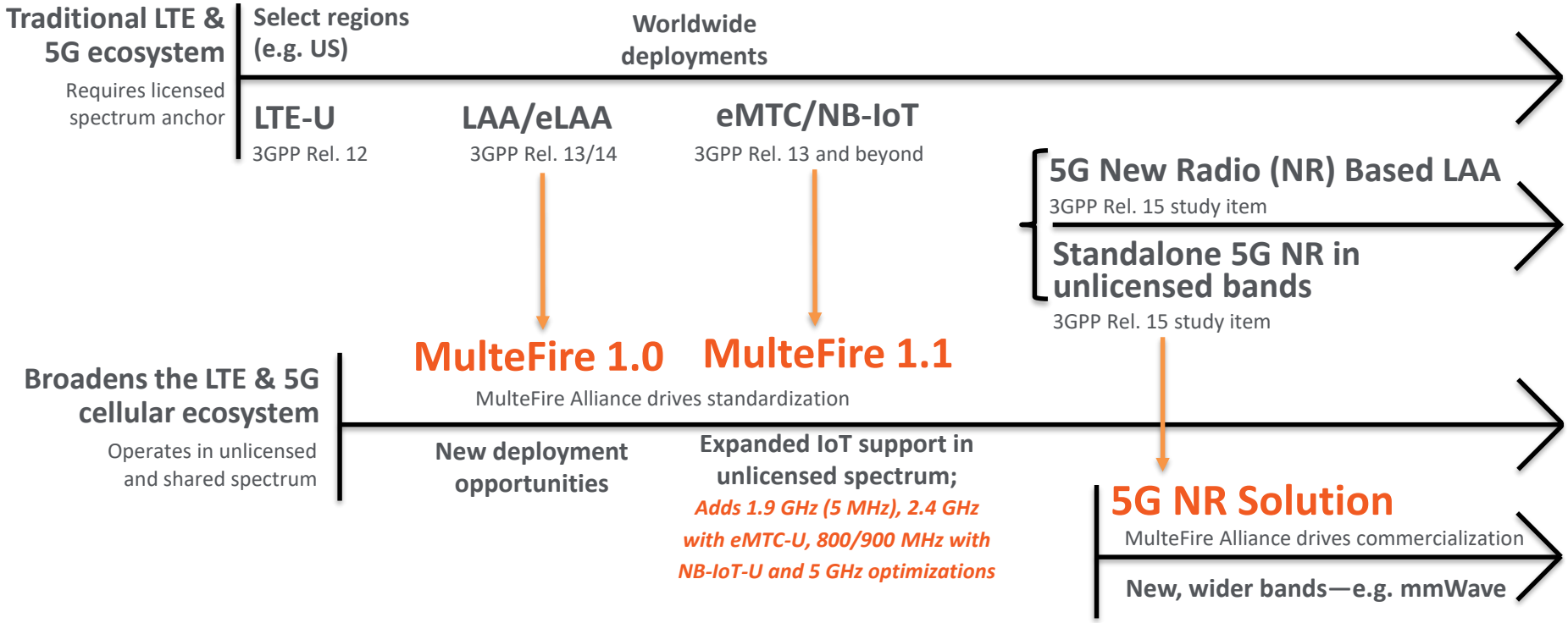
Broadens LTE ecosystems to enhanced and new deployment opportunities, suitable for neutral host

Wi-Fi[4]

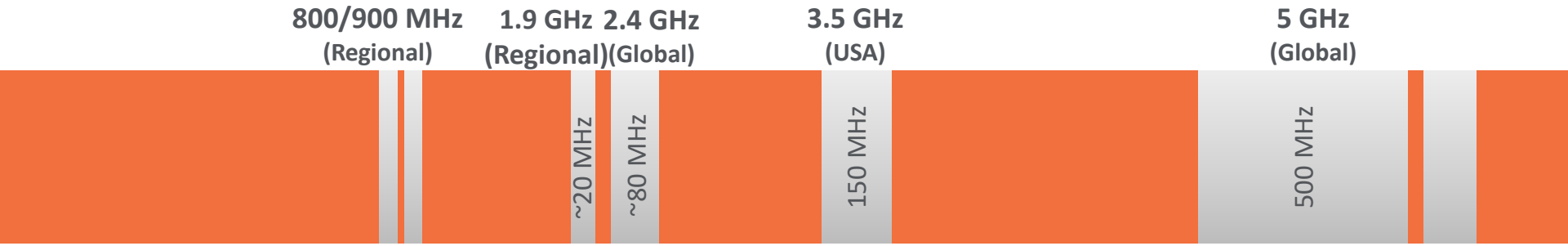
Evolving for enhanced performance and expanding to new usage models, used today as neutral host

1. Licensed-Assisted Access (LAA), also includes enhanced LAA (eLAA); 2. LTE Wi-Fi Link Aggregation (LWA); 3. LTE Wi-Fi radio level integration with IPsec tunnel (LWIP); 4. 802.11ac/.11ad/.11ax/.11ay

MulteFire Technology Roadmap: Based on 3GPP Standards



Standalone Deployment in Unlicensed and Shared Spectrum



MulteFire 1.0/1.1
For mobile broadband & high-performance IoT. Carrier bandwidth: 10/20 MHz (5 MHz for 1.9GHz)

MulteFire 1.1 eMTC-U
Broadest range of narrowband IoT use cases, Carrier bandwidth: 1.4 MHz

MulteFire 1.1 NB-IoT-U
For low-power, wide-area (LPWA) IoT use cases
Carrier bandwidth: 200 kHz

[1] Use of MulteFire in 3.5 GHz in US possible but not a target band and not part of CBRS focus (regular TD LTE)

[2] Use of NB-IoT-U at 2.4 GHz also possible

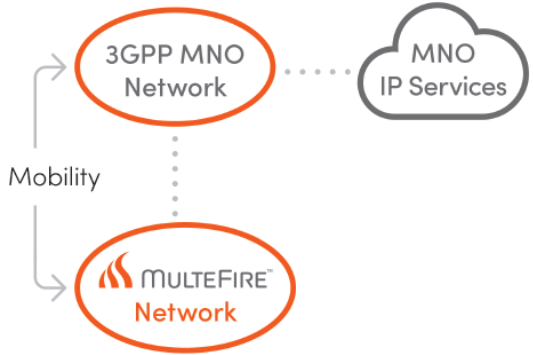
[3] Use of eMTC-U at sub 1 GHz also possible

MulteFire 1.0

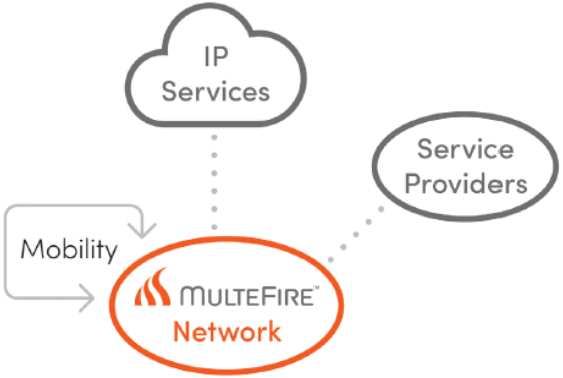
Architecture Options and Radio Features

Release 1.0 End-to-End Network Architecture

- Release 1.0 based on 3GPP standards (LAA/eLAA) was completed in 2017
  - Implements Listen-Before-Talk (LBT) for fair co-existence with Wi-Fi and LAA
- Specification delivers end-to-end architecture, including interworking for neutral hosts , private networks and interworking with 3GPP networks
  - Enables access authentication with or without a SIM card



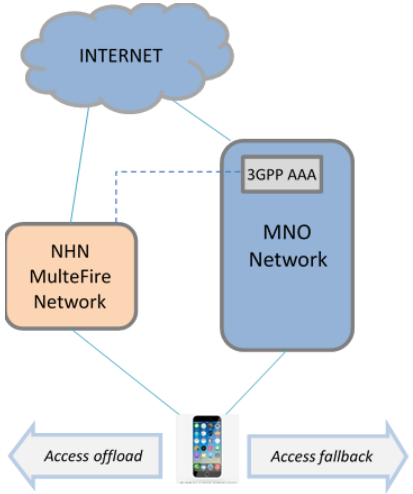
Traditional Access Mode : Single network operator, e.g. private IoT Network or MNO



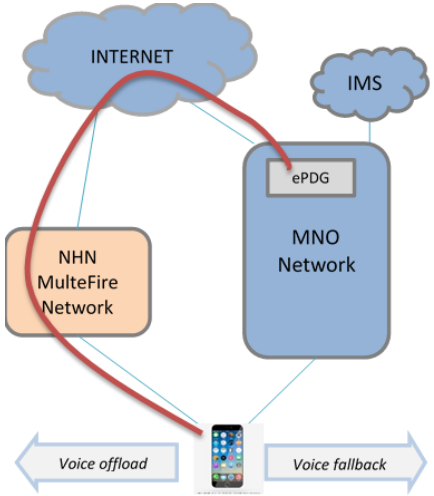
Neutral Host Access Mode: Self-contained, single deployment can serve multiple operators

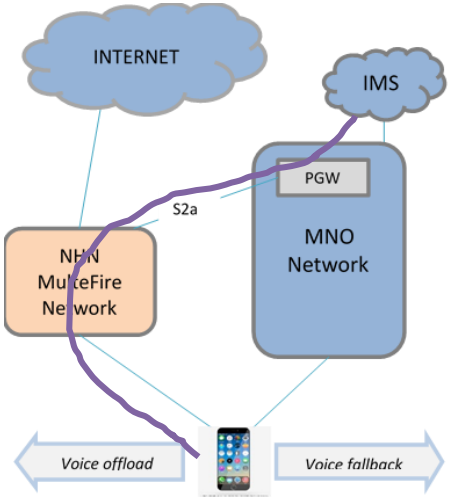
Release 1.0 Core Network Design

Mobile Access

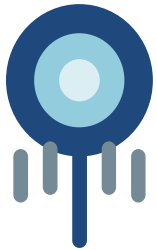


Mobile Voice





Release 1.0 Radio Design Brings LTE Benefits to Unlicensed Spectrum



Coverage

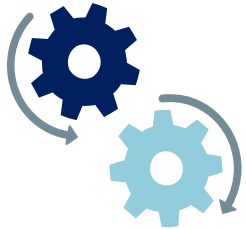
- Retains LTE's deep coverage characteristics
- 5-6dB link budget advantage over Wi-Fi

Capacity

- Leverage LTE link efficiency and MAC[2]
- Significant gains (~2X) over Wi-Fi

Mobility

- Seamless & robust mobility and continuity to WAN
- Significantly better than Wi-Fi, esp. outdoor, 50 km/h



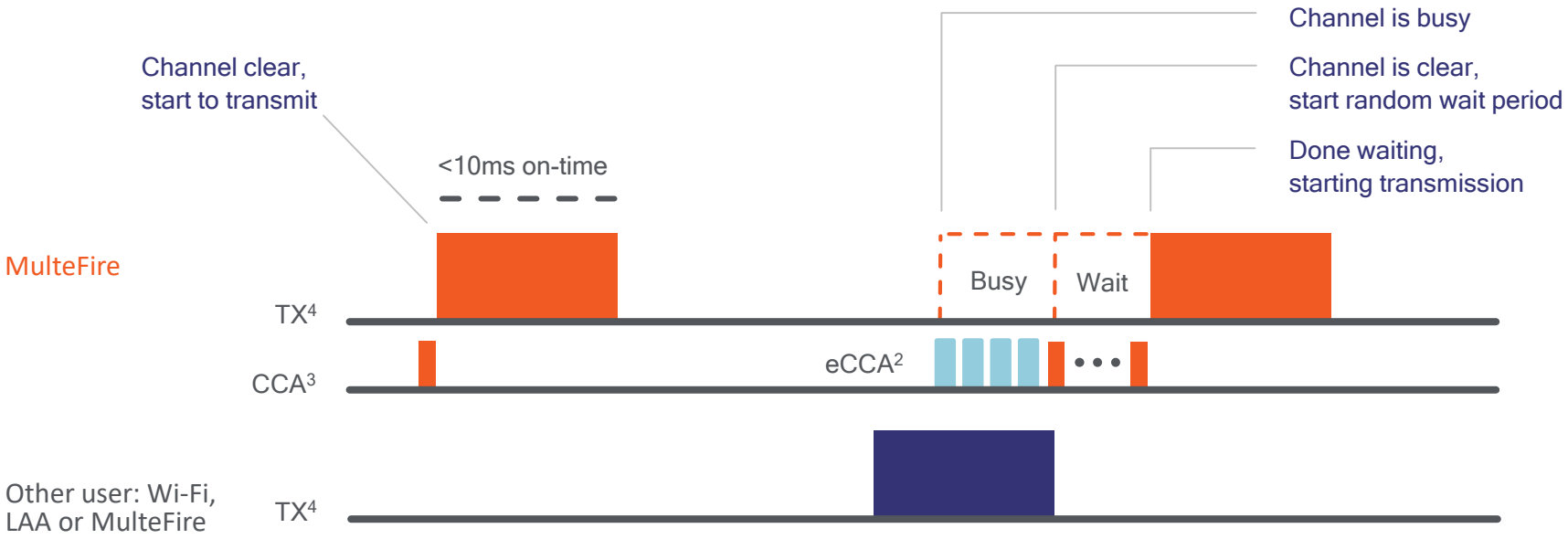
Robustness

- More predictable & robust performance than Wi-Fi
- Forward HO[3] enables recovery when RLF[4]

1) Signal-to-interference-plus-noise ratio (SINR); 2) Media Access Control (MAC) Layer; 3) Handover (HO); 4) Radio link failure (RLF)

Listen-Before-Talk Ensures Fair Sharing in Unlicensed Spectrum

Same global over-the-air contention mechanism for MulteFire, (e)LAA and Wi-Fi[1]



1) LBT applies on LAA, eLAA, MulteFire, and Wi-Fi in the proposed next release of ETSI EN 301 893; 2) Extended CCA (eCCA): If channel is busy (CCA[3]) wait until cleared and then perform a random number of additional successful CCAs[3] before starting transmission; 3) Clear Channel Assessment (CCA): Sense if channel activity is below a certain energy detect (ED) threshold and if so start transmission; 4)Transmit (TX)

Announcing MulteFire Release 1.1 Completion

MULTEFIRE®

- **Enhanced MulteFire 1.0 Broadband Services in the Global 5 GHz Unlicensed Band**
  - Delivering more robust mobility, faster uplink data transmissions, improved downlink coverage, and adds SON capabilities
- **Added Additional Spectrum Bands Focusing on IoT**
  - Including MulteFire 1.9 GHz (for the unlicensed part in 3GPP defined Band 39), also known as sXGP in Japan, which is ready for commercial deployment in Japan with support from the XGP Forum and an ecosystem of TD-LTE devices in place that support Band 39 today
- **Expanded IoT Services with Low Power Wide Area Support**
  - 800/900 MHz with NB-IOT-U and 2.4 GHz with eMTC-U support
- **Release 1.1 will be published to Alliance members in January 2019 with public availability by mid-2019**

MulteFire Release 1.1

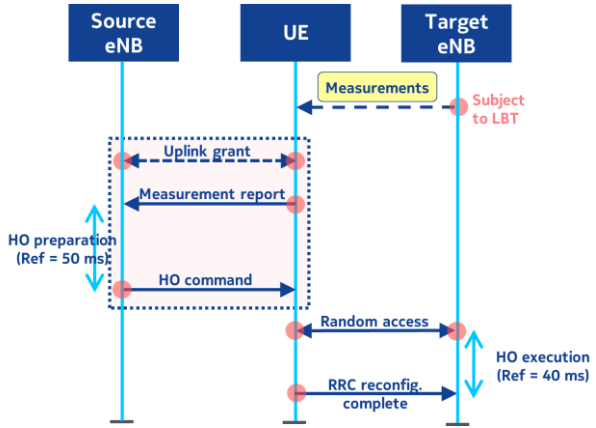
5 GHz Enhancements for Release 1.0

More Robust Mobility – Autonomous UE Mobility (AUM)

5 GHz enhancements in Release 1.1 for more robust mobility in up to 50 km/h speed

NOW: Coexistence requirements (LBT) may delay or block critical handover messages

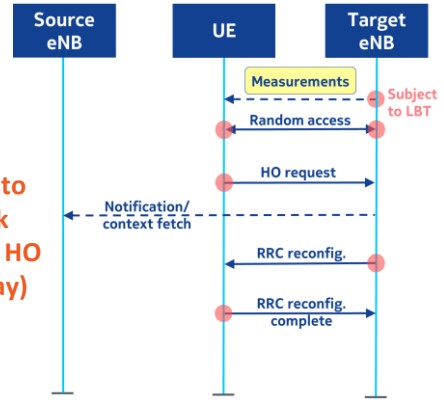
- Source eNB may not get UE's measurement or does not send HO command to UE early enough
- Delay means signal quality could drop and HO signaling may fail if attempted too late



NEW: UE performs autonomous handover (HO) without explicit network command

- Avoids time critical signaling just before HO
- UE performs autonomous HO using pre-configured parameters at target eNBs
- Shifting signaling to the target eNBs so HO works at delay or radio link failure

HO works even if measurement not sent to source (e.g. Radio Link Failure), or source sends HO command too late (delay)



Shorten Access Time – Grant-less Uplink (GUL)

5 GHz enhancements in Release 1.1 to allow faster uplink data transmissions

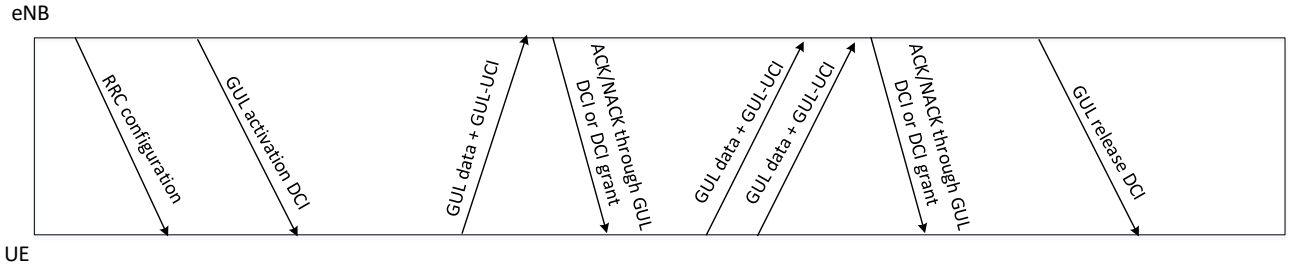
NOW: Risk of increased uplink (UL) delay due to LBT and need for downlink (DL) control signaling

- Waiting for scheduling request (SR) opportunity
- Waiting for UL grant, actual UL transmission
- All are potentially subject to LBT failure

NEW: Grant-less uplink where UE can start transmitting immediately

- If UE succeeds LBT within a predefined set of radio resources, it can transmit immediately
- Doesn't suffer from the multiple contentions imposed on scheduled UL access

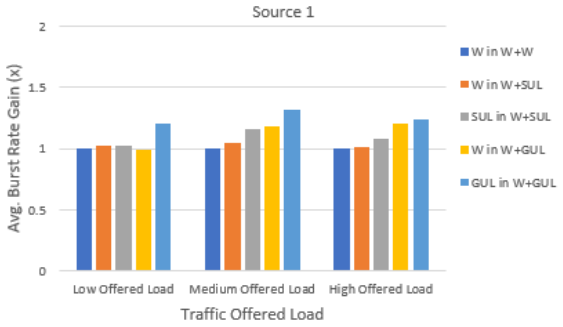
eNB configures UE for GUL operation Inspired by the 3GPP semi persistent scheduling (SPS) framework

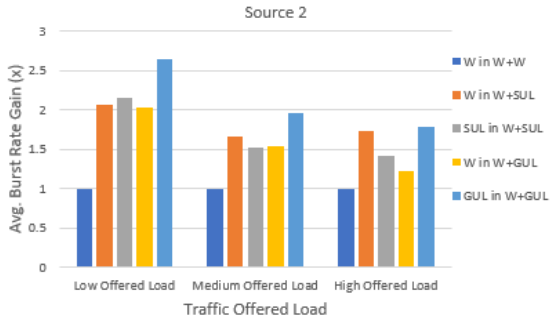


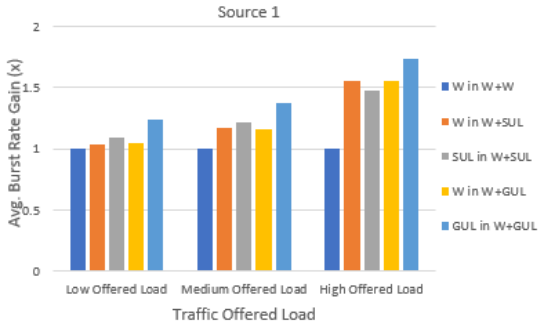
GUL allowed if channel is free—only for configured UE

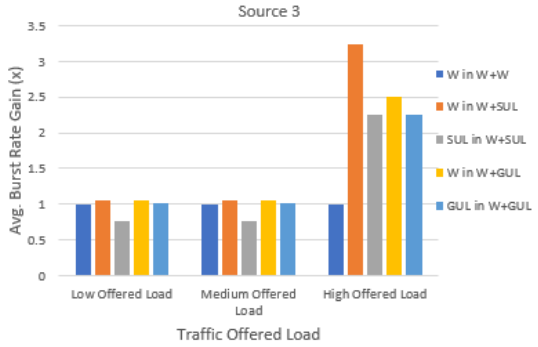
Shorten Access Time – Grant-less Uplink (GUL) Simulations

5 GHz enhancements in Release 1.1 to allow faster uplink data transmissions









Balanced Coverage – Wideband Coverage Enhancements (WCE)

5 GHz enhancements in Release 1.1 to improve downlink (DL) coverage

NOW: Imbalance between DL and the better UL needs to be closed

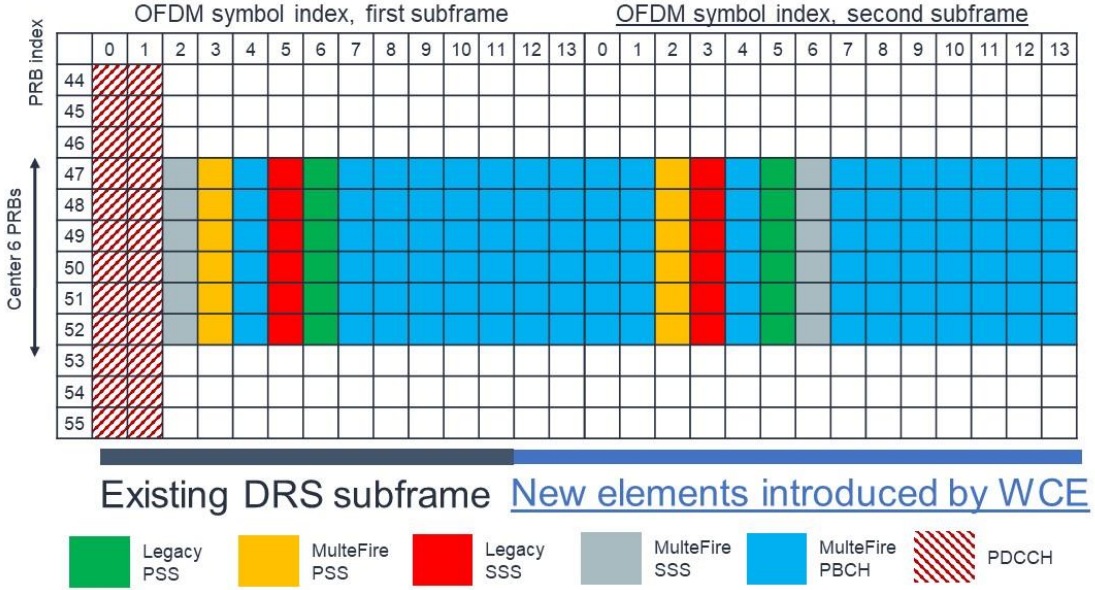
- Up to ~8db imbalance

NEW: Wideband coverage Discovery Reference Signal (DRS) subframe structure

- More resources -> better coverage

Imbalance due to e.g.:

- Difference in noise figure between UE and eNB
- Power Spectrum Density (PSD) limitations
- Bandwidth limitations on some DL channels
- DL control and data channels less effective in supporting lowest Modulation and Coding (MCS)



Double amount of synchronization signals

Triple amount of PBCH resources

PBCH is repeated with same redundancy version

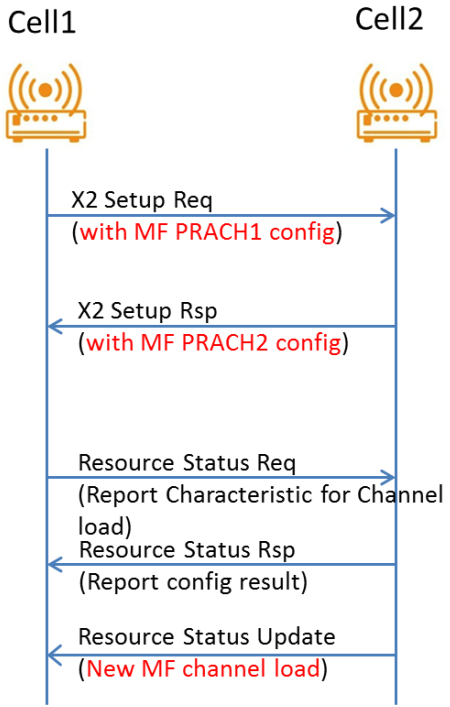
2 ms structure for higher access priority for LBT

Simplified Deployment and Configurations – Self-Organized Networks (SON)

5 GHz enhancements in Release 1.1 to support SON for MF V1.0 Networks

Self-Optimizations in MF

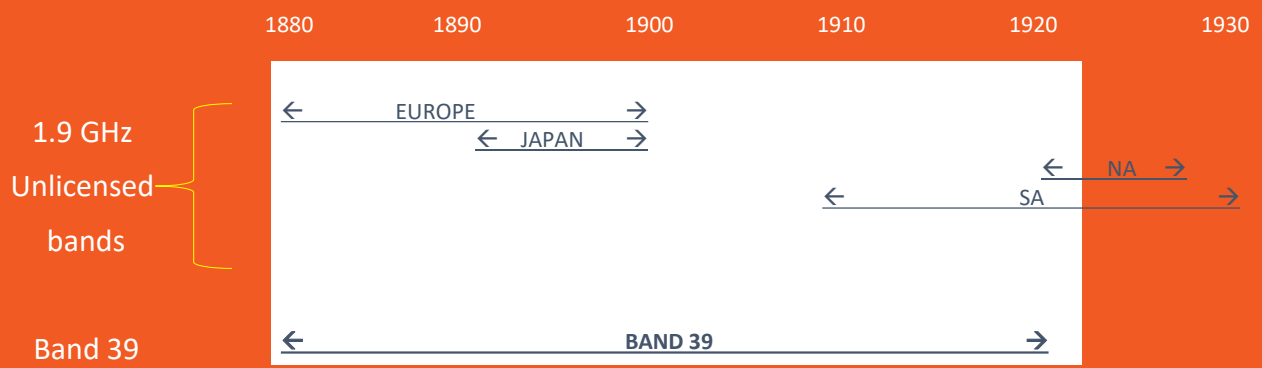
- RACH-Optimization
  - UE reported information about LBT failure for RACH preamble transmission.
  - X2 exchanged RACH information for MF
- Radio Link Failure (RLF)
  - UE check the NHN-ID for RLF-report, if same as the NHN-ID restored when RLF happens, then UE sends the RLF-report.
- Mobility Load Balancing (MLB)
  - X2 exchanged MF channel load information
    - Channel occupancy considering the time domain ratio cannot be used due to LBT and
    - Channel own usage Indicates the time domain ratio of channel usage by the DL and UL transmissions of the cell.



MulteFire Release 1.1

IoT and Spectrum Enhancements

MulteFire 1.1 Support for 1.9 GHz; sXGP in Japan



Band 39 covers most 1.9GHz unlicensed bands

TD-LTE Band 39 ecosystem has 1358 types of devices – Based on January 2017 GSA

sXGP – MulteFire 1.1 Variant in 1.9 GHz (DECT) Bands

1.9 GHz is ready for deployment in Japan and is being driven by the XGP Forum

Targeting enterprise IoT use cases operating in 3GPP Band 39 (1.9 GHz)

- Japanese regulation allows MulteFire to use existing Band 39 devices (such as Cat 5/1 devices in 5 MHz)

Ecosystem in place – ready for commercial launch

- Massive TD-LTE ecosystem with more than 1 billion devices supporting Band 39 today - no device impact
- MulteFire 1.1 Band 39 eNBs are commercially available today—handles coexistence

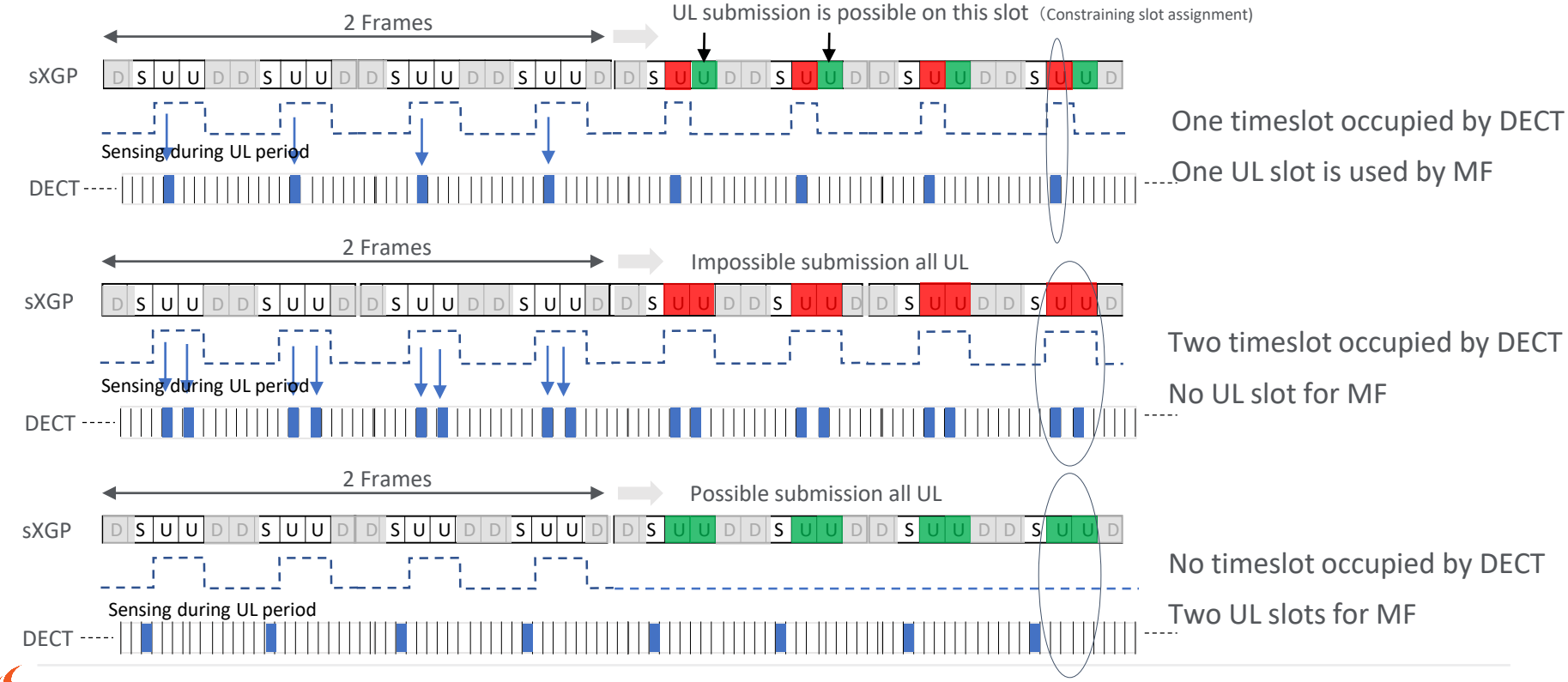
Co-existence is driven by eNB using standard TD-LTE UE Band 39 devices

- Co-existence is driven by hourly eNB Listen-Before-Talk in uplink and downlink
- Backs off for existing DECT services – not allowed in a slot occupied by DECT
- Utilizes DECT dynamic channel allocation to push DECT users to other frequencies

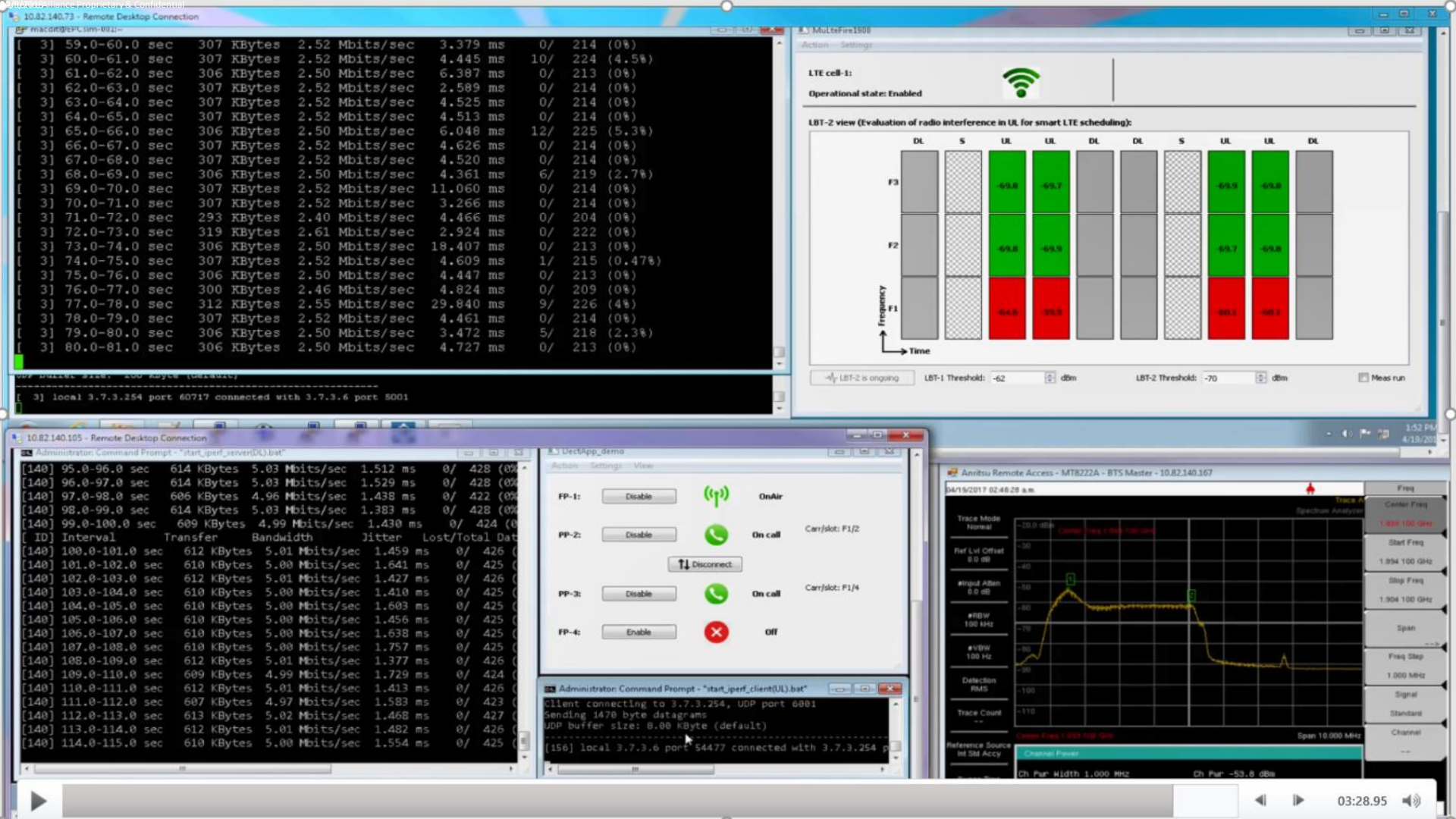
MF1.1 supports carrier bandwidth 5 MHz TDD (Cat 5/1/0) and can support eMTC and NB-IoT based on Band 39 availability

MulteFire Uplink Transmission Not Allowed if Slot Occupied by DECT

Japan co-existence with DECT for MulteFire 1.1



Case: DECT is exiting during Guard period of S-Frame

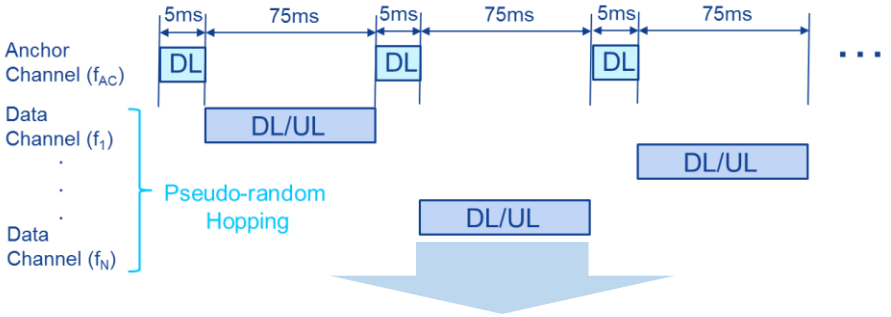


MulteFire Operation in 2.4 GHz Band – eMTC-U

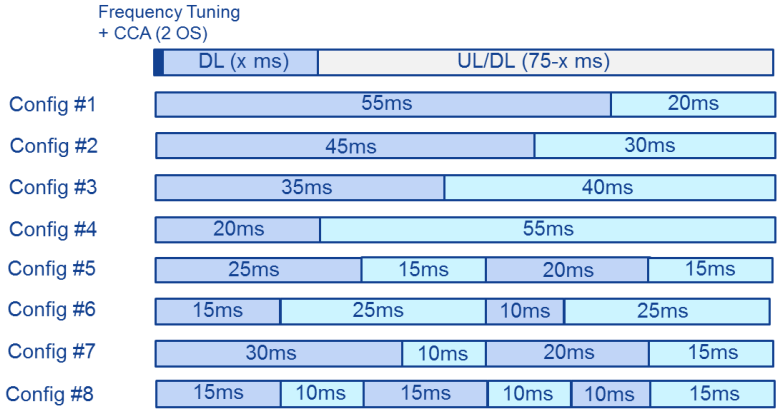
MulteFire 1.1 expansion of range of services

- Building on top of 3GPP eMTC, but subject to LBT/DC to comply with EU regulations
- Same implementation for both FCC and EU regulations
- **1.4 MHz channel bandwidth**
    - 6 Physical resource blocks (PRB) operation (1.08 MHz nominal), 16 or 32 data channels
- **LBT before** each initial **DL** transmission both for anchor and data channels
- **UL access** is limited by **duty cycle** (DC ≤ 50%, i.e. 5ms Tx on followed by a 5ms gap)
- 80 ms anchor channel periodicity with 16 data channels (160 ms with 32 data channels), 75 ms data channels
- 8 pre-defined data channels for various UL/DL configurations

Frame structure



- 8 pre-defined data channel configurations:

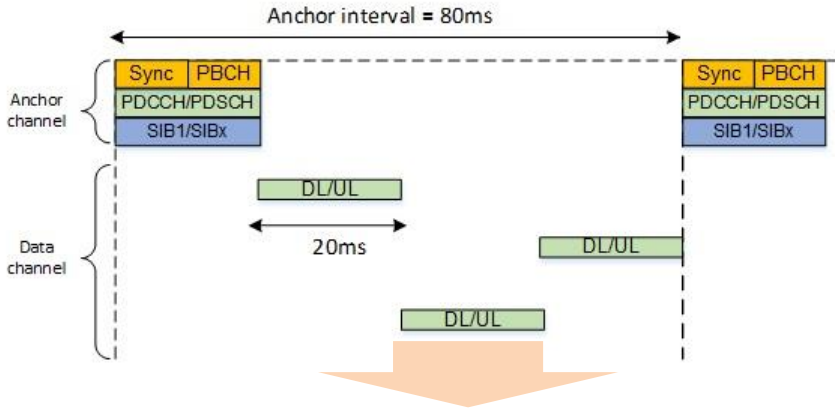


MulteFire Operation in 800/900 Unlicensed Band – NB-IoT-U

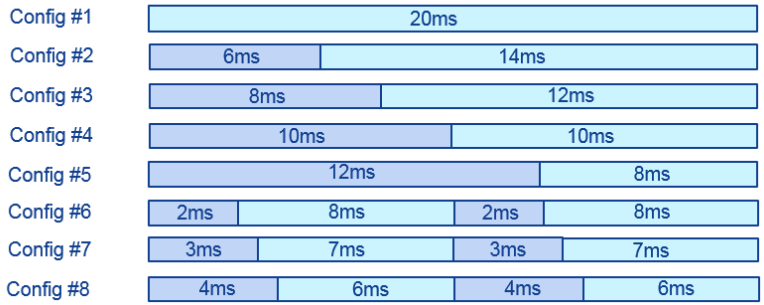
MulteFire 1.1 expansion of range of services

- Building on top of 3GPP NB-IoT
- Two different implementations for FCC and EU regulations
- 80 ms anchor channel periodicity for FCC
    - No duty cycle requirement by FCC
    - 3 * 1 PRB (540 kHz) DL only for FCC
- 8 pre-defined 20 ms data channels for various UL/DL configurations for FCC
    - 1 PRB each (180 kHz) DL/UL
- EU regulations to meet duty cycle ≤ 10% for both DL & UL
    - 1280 ms anchor channel periodicity with 1 PRB (180 kHz) DL only for EU
    - Data punctured by the anchor channel
    - Data channel = nF frames (nF = 16, 32, 64, or 128), frame duration = 1280/nF ms

Frame structure (Sync = PSS + SSS)



- 8 pre-defined data channel configurations:

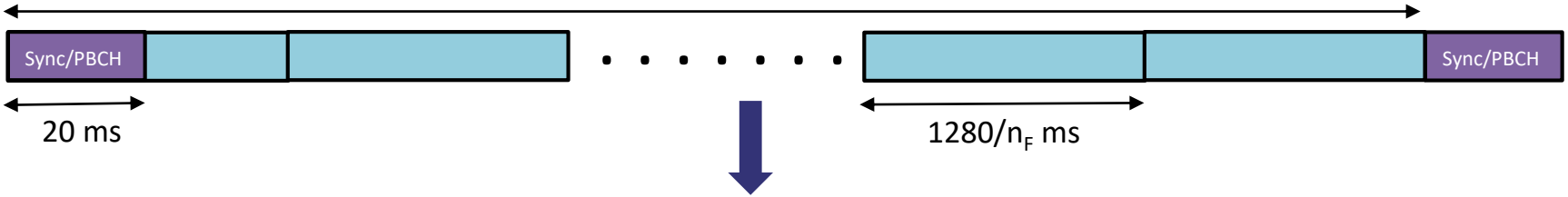


NB-IoT-U – EU Design

- Anchor channel 1 PRB (180 kHz), DL only, 20 ms dwell, 1280 ms anchor channel periodicity.
- Data channel 1 PRB each (180 kHz), DL/UL, 1280ms, punctured by the anchor channel.
- Data channel = n_F frames (n_F = 16, 32, 64 or 128), frame duration = 1280/n_F ms
- DC for both DL and UL (DC ≤ 10%)

Frame structure (Sync = PSS+SSS)

Anchor interval = 1280 ms = n_F frames (n_F = 16, 32, 64 or 128)



4 pre-defined frame configurations:

Config #1 (n_F = 16): 8 ms (DL) + 72 ms (UL)

Config #2 (n_F = 32): 4 ms (DL) + 36 ms (UL)

Config #3 (n_F = 64): 2 ms (DL) + 18 ms (UL)

Config #4 (n_F = 128): 3 ms (DL) + 7 ms (UL)

Moving Forward… Release 1.1 and Beyond

- MulteFire Release 1.1 specification is completed and will be published to members and will be made publicly available in 2019
    - 5 GHz enhancements to Release 1.0
    - IoT optimizations, including eMTC-U and NB-IoT-U
    - Additional spectrum bands, including 1.9 GHz in Japan, global 2.4 GHz and 800/900 MHz
- MulteFire Alliance supports migration path to 5G NR Solution in unlicensed spectrum

MULTEFIRE®