

5G and Beyond Testbed Key Attributes

IEEE 5G and Beyond Testbed Workshop
September 24, 2017

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INTERDIGITAL.



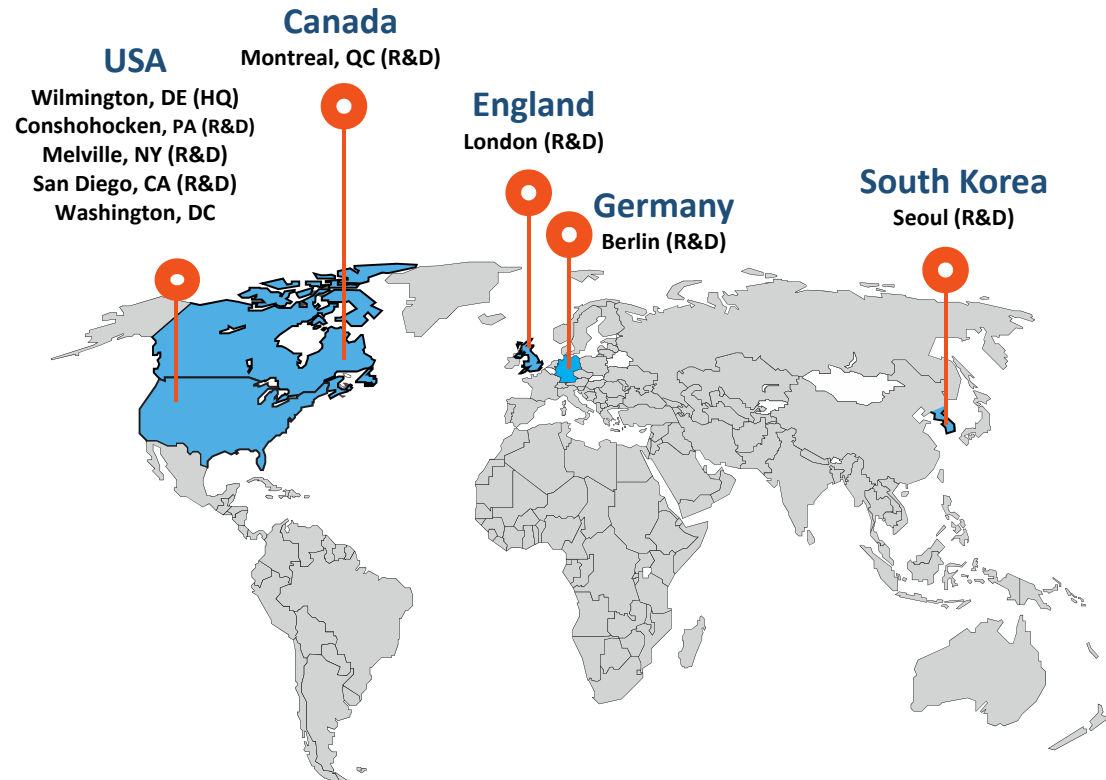
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Overview

- 5G wireless development activities
- Recent Testbed Experiences
- 5G and Beyond Wireless Testbed Keys
- Summary

InterDigital

- Over four decades of wireless technology Development
 - Founded in 1972
- ~ 180 engineers
 - 80% hold advanced degrees
- Contributing to global wireless standards
- Developing solutions for more efficient broadband networks
- NASDAQ:IDCC



InterDigital – Wireless Technology Development

Look to collaborate with other companies, research centers, universities and public authorities.

Has been a top-4 standards contributor for successive generations of wireless technology, including 3G and LTE (as per PA Consulting)

Are impartial advocates for what we think improves the entire industry.

The mobile industry has cycles of hype and over exuberance. Our research, opinions, and the market research we commission is focused on injecting realism.

The Time to Engage in 5G is Now!

We are active participants and contributors to 5G wireless, network, and video standards

- **3GPP – 5G New Radio (NR)**

- All radio network layers, core network, interfaces, non-access stratum, ...
 - RAN 1/2/3/4 (Physical Layer)
 - SA/CT (CN Architecture, Interfaces, NAS)

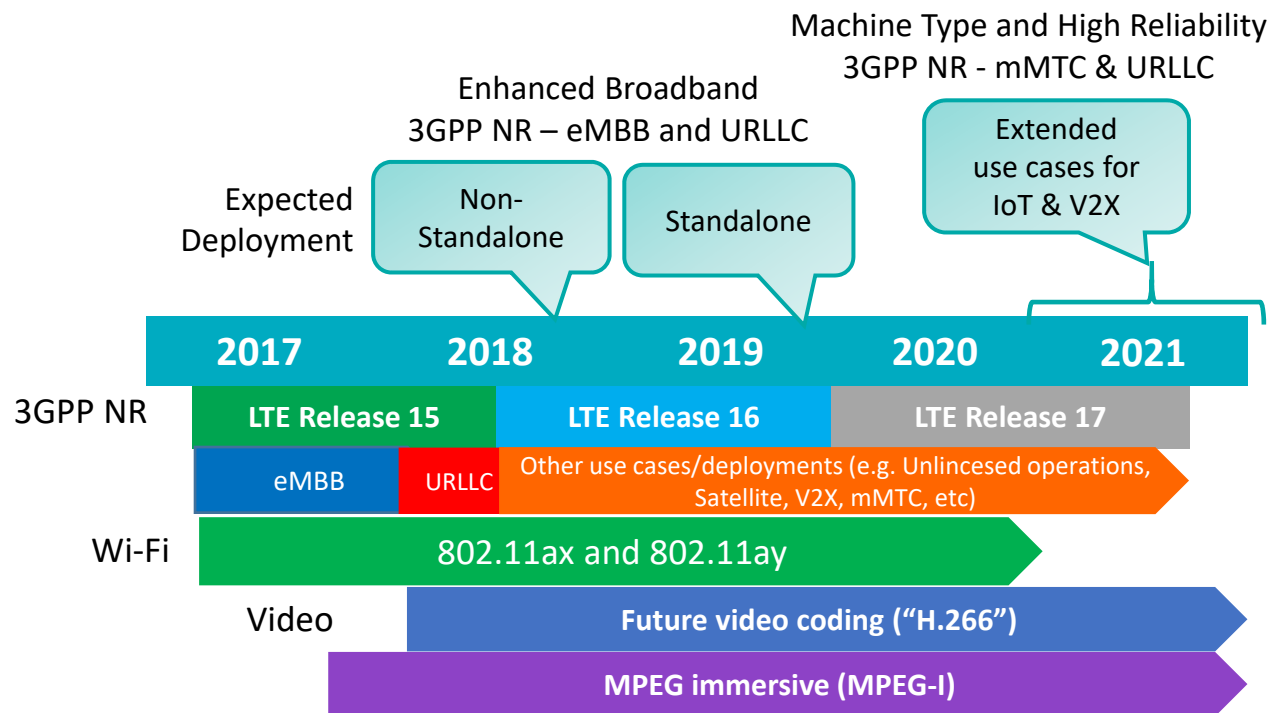
- **Wi-Fi**

- High throughput, millimeter wave, wake up receiver, ...
- 802.11ax, xy, ba

- **Video**

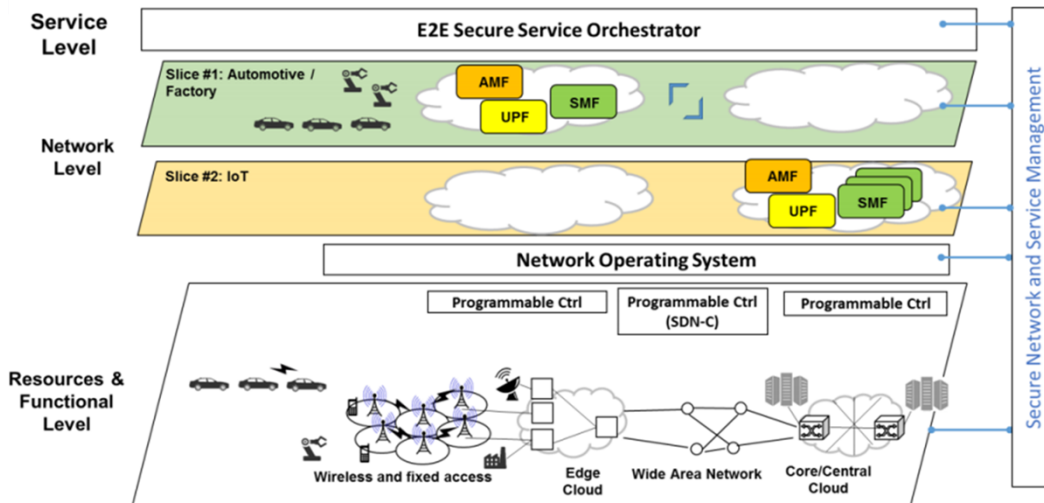
- Future video coding standards (“H.266”)
- MPEG immersive standards suite: coding, packaging, 360 deg, virtual reality, augmented reality, point cloud, ...

- **IETF, ETSI, ITU**



5G – Emerging Architecture and Enabling Technologies

5G Architecture Themes: Flexibility, Scalability

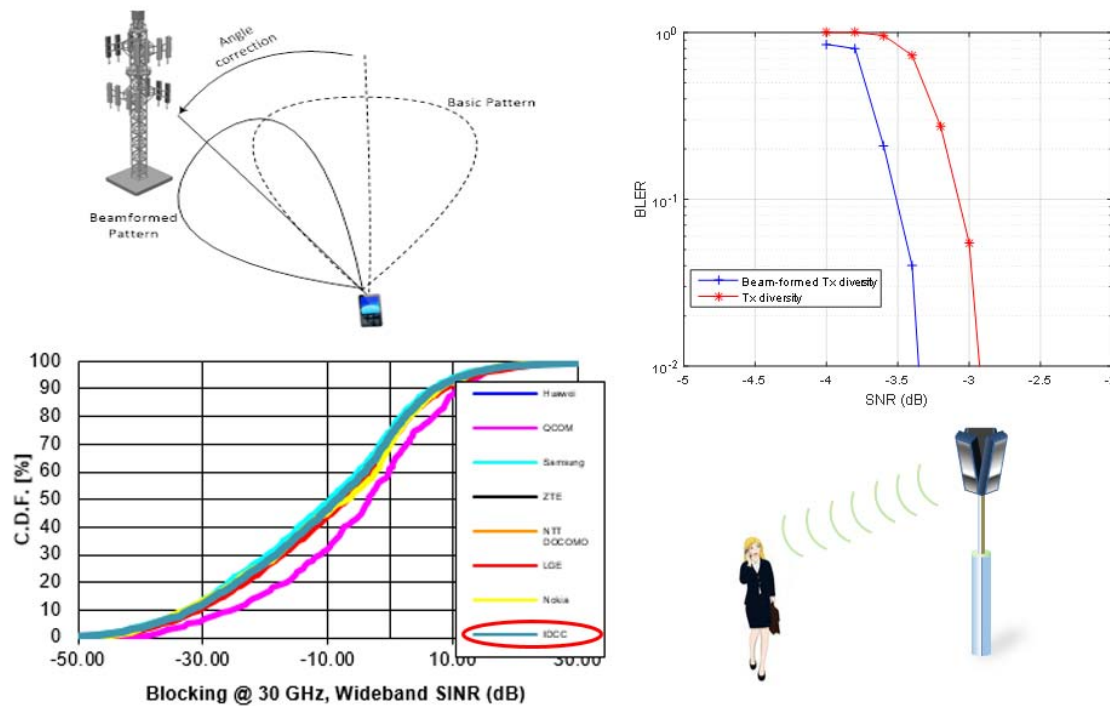


Source: 5G-PPP Architecture WG
View on 5G Architecture (Version 2.0)

- 5G New Radio
 - Fiber-like performance
 - However, 5G is Multi-RAT
- Network Function Virtualization
 - Network realized in software: Core and RAN
 - Cloud resources throughout the network
- Programmable Network
 - Flexible orchestration of network resources and infrastructure: RAN, core, transport, etc.
- Network Slicing
 - Self-contained, independent network partition including all segments: radio, core, transport, and edge.
 - Multi-domain, multi-tenant

Extensive Simulation Activity

Extensive link and system level simulations support 3GPP and Wi-Fi contributions



At the Forefront of Emerging Technology

History of being an early player in emerging technology development

- Early prototypes for 5G Millimeter Wave
- Early contributor to launch of today's IoT standards
- Diverse approaches to Spectrum Sharing
 - TVWS
 - Dynamic Spectrum Management
 - Cellular Unlicensed
- Innovative solutions for network routing using SDN
- Active member in key organizations



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February 27, 2015

InterDigital, imec and Peraso Demonstrate World's First WiGig-Based Millimeter Wave Mesh Backhaul System

Collaboration Integrates 60 GHz Phased Array, WiGig Baseband Chip and Mesh Software Into InterDigital's EdgeHaul(TM) Small Cell Backhaul Solution

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July 29, 2015

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October 27, 2011

World's First IP-over-ICN-over-SDN Demonstration

InterDigital Participates in Multi-Vendor Demonstration of New ETSI Standard for Wireless Machine-to-Machine Communications

Newly published standard enables cellular operators, service providers and device manufacturers to accelerate the deployment of new M2M services and applications

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October 22, 2012


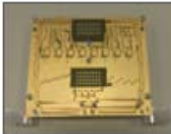
InterDigital Showcases World's First Demo of Wi-Fi Access over Dynamically-Selected TV White Space Spectrum At DySPAN 2012

Company's Dynamic Spectrum Management Platform Easily Adaptable to Multiple Spectrum Bands, Supports Diverse "Shared Spectrum Access" Applications



Wireless Platforms, Demonstrations and Testbeds

InterDigital 5G Access

EdgeLink™ for 5G 60GHz Fixed Wireless Access	5G 70 GHz Low- latency Demo	Dual 32 Element 60 GHz Phased Array
		

From 5G Prototypes to 5G Standards

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The collage displays the following components and their locations:

- GPS**: Located on the front panel.
- T-Cell Board**: Located on the front panel.
- Integrated Modem and Processor**: Located on the front panel.
- Processors (600, 800, 900)**: Located on the front panel.
- Antennas**: Located on the front panel.
- GSM**: Located on the back panel.
- U.S. Radio**: Located on the back panel.
- Antenna**: Located on the back panel.
- Additional Chips**: Located on the internal components.
- Power Supply**: Located on the internal components.
- GSM/GPRS/EDGE/UMTS**: Located on the internal components.
- Backplane**: Located on the internal components.
- Equipment Board**: Located on the internal components.
- Service Based Components**: Located on the internal components.

Advanced Waveforms: InterDigital's Proof of Concept

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Mobile World Congress 2015

Fall 2015 Outdoor Range Testing

Mobile 1

Mobile 2

3.28Gbps

4K Video up to 1080Mbps @ Application Layer

1080P Video over Ethernet

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5G Berlin Testbed

3 Edgeline mmW Nodes –
across the HHU and Berlin Technical University campuses

Outdoor Antenna Installation

Indoor Lab Deployment

FLIPS Trial at UK's Bristol is Open

- Multi-cast technology for Mobile Edge Computing that improves network efficiency and user experienced latency
- Technology deployed in 6 fibre-enabled SDN-connected lamp posts
 - Parallel FLIPS & legacy IP deployment
- Open trial from July 10 -23, 2017
- Web-based mobile game
 - Solve tourism riddle through uploading AI content to unlock parts of the riddle
 - Upload to central site
 - Regularly replicated to local repositories using HTTP multicast for PoC demo
 - Content consumption through local repository



Bristol is Open

Open Programmable City

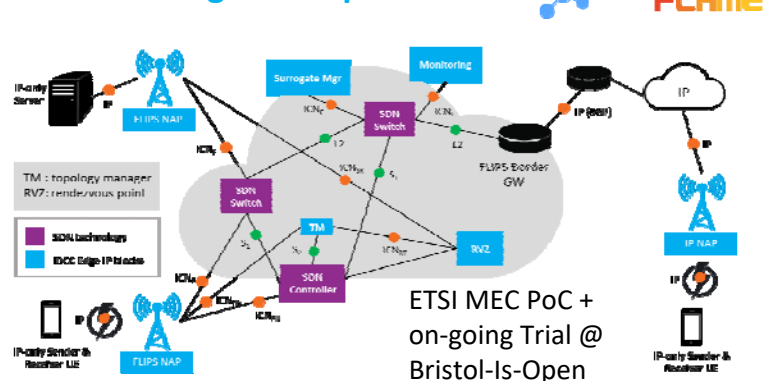


- City wide initiative utilizing deployed fiber connectivity
- Mix of technologies and experiments – from sensors to smart phones



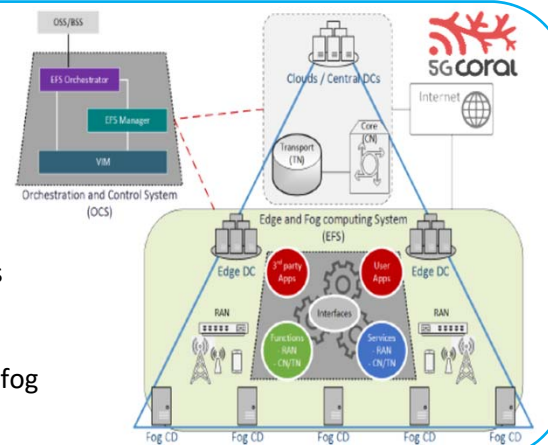
InterDigital – MEC R&D Activities...a snapshot...

FLIPS - An Edge IP Proposition

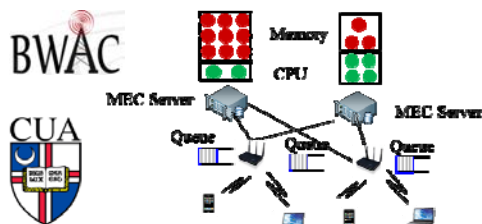


5G Virtualized Access Network Living at the Edge

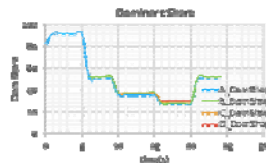
Multi-RAT Access enabled via an integrated and virtualized edge, fog system



MEC Resource Management



- Sponsored research
- Distributed orchestration across the heterogenous, constrained edge



- Active ISG Member
- Upcoming Plenary Meeting at InterDigital, Melville Office in October
- First International Workshop on Edge and Fog Systems for 5G & Beyond (IWEF)
- Barcelona, Spain on April 15, 2018

<http://wcnc2018.ieee-wcnc.org/workshop/first-international-workshop-edge-and-fog-systems-5g-beyond-iwef/first-international>





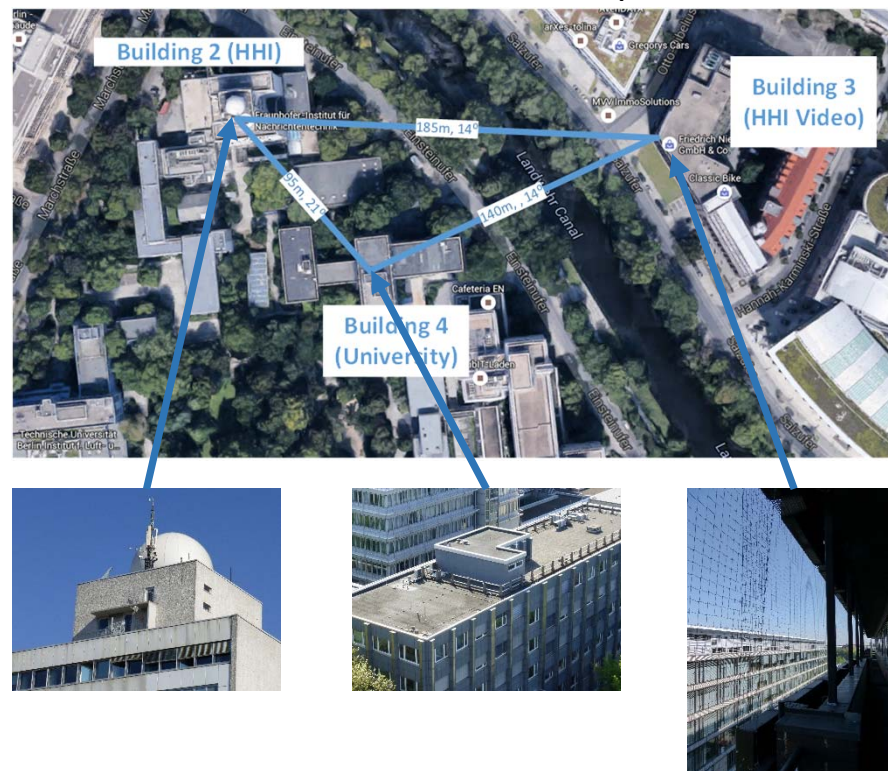
5G Berlin | © Fraunhofer Institute

EdgeLink at 5G Berlin Testbed

5G Crosshaul

Phase 1 Berlin Trial - Sept 2016

- InterDigital EdgeLink System deployed into the 5G Berlin Testbed, hosted by Fraunhofer HHI – under the 5G Crosshaul project
- 3 EdgeLink mmW Nodes – outdoor installation on buildings within the Fraunhofer and Berlin Technical University campuses:
 - Ranging from 95 to 185 meters distances
 - 1 GW + 2 non-GW Nodes
- Multiplexing of Fronthaul and Backhaul traffic over the InterDigital mmW EdgeLink Mesh transport network:
 - Backhaul == Commercial LTE Small Cell
 - Fronthaul == Cloud-RAN (remote radio units and centralized baseband) provided by a Crosshaul Partner.
 - Execute a range of experiments considering traffic loading profiles under real-world conditions.



US-Ignite PAWR Benefits

• Industry Benefits

- Addressing significant pre-competitive research challenges not easily feasible for individual companies
- Creating city scale real-time testing environments to accelerate wireless and networking technologies
- Enhance Industry-academic partnerships
- Help to sustain US leadership by shaping and securing funding for fundamental wireless research

• InterDigital Benefits

- To continue our heritage as a thought leader in 5G by collaborating with world class Universities and Industry in the US.
- Promote and expand the US as a leader in mmW and 5G technology
- Bring our leadership and experience to PAWR having worked with EU funded H2020 projects
- Opportunity to deploy and test our technology in real-world environments.

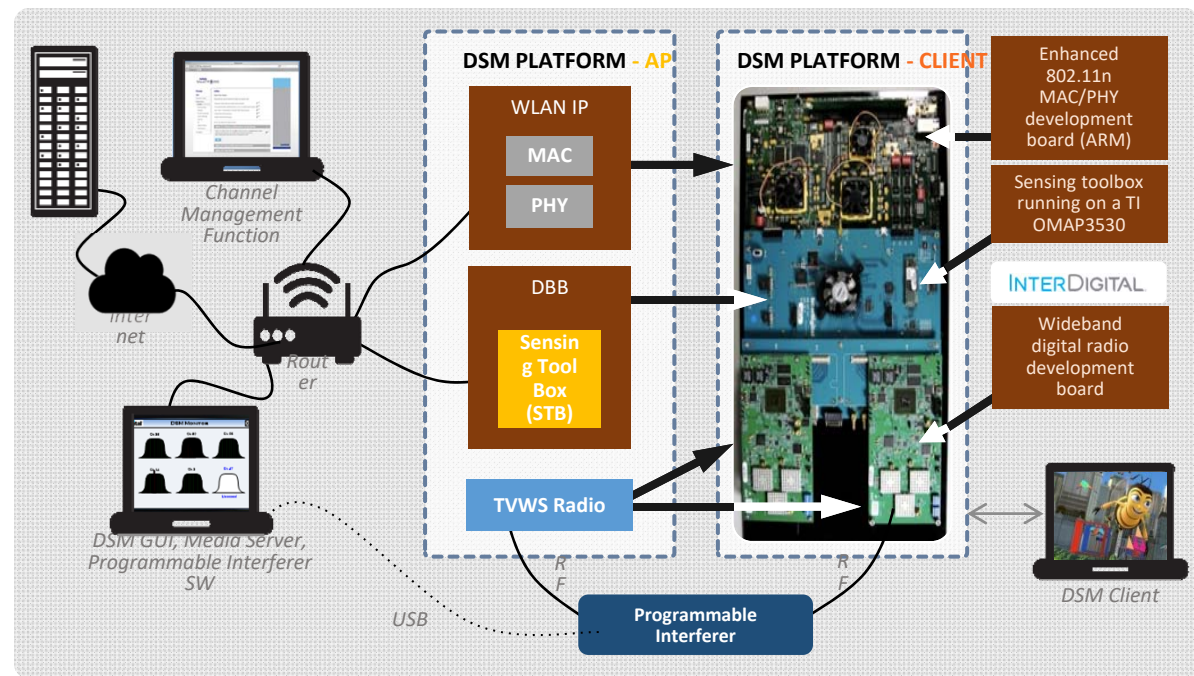


DSM Wi-Fi Platform

3.5 GHz and TVWS Operation



- 200 MHz coverage in 3.5 GHz or TV White Space frequency bands
- Dynamic allocation & aggregation of up to 4 non-contiguous channels
- Wi-Fi based physical layer for coexistence
- Integrated sensing for channel selection & interference management
- Compatible with certified geo-location database
- Aggregated data rates up to 72 Mbps



5G Testbed Key Attributes

5G Testbed – Addresses Multiple Technologies

- Broad range of topics
 - Spectrum access
 - Advanced Waveforms
 - mmW
 - Advanced MIMO
 - Flexible/Full Duplex
 - internet of things
 - Security
 - RF Fingerprints
 - wide-area wireless backhaul
 - Measurements
 - MEC

5G Testbed Usability

- Reasonable learning curve
- 'Hello World!' + examples
- Operable by entry level technical talent
- Clear Interfaces and Documentation
- Utilize current user interface approaches
- Remote Access Capabilities
- Reprogrammable when necessary
- Extensible
- End to End System
- Ability to test HW and SW
- More than adequate Processing Horsepower

5G Testbed Reproducibility

- Platforms setup, maintained, logged/documentated
- Follow rigorous scientific standards
- Repeatable Results and Accuracy

5G Testbed Interoperable

- Prevent silos within research
- ecosystem
- Well-defined interfaces
- Interconnection with other Testbeds
- Reuse of other Testbed interfaces

5G Testbed Programmability

- Programmable at multiple levels
 - Such as radio, resource allocation, backbone, etc.
- Clearly defined interfaces and APIs.
 - Well documented
 - Coding Examples Provided
 - Simulation Platforms available for pre-deployment testing and debug

5G Testbed Open Access

- Accessible by the research Teams
- Community Involvement and buy-in
- Fairness in access

Summary

- InterDigital is actively engaged in the development of 5G technology and welcomes the opportunity to collaborate on the advancement and improvement of 5G
- InterDigital has been involved in various wireless testbeds.
 - recently Bristol is Open and 5G Berlin.
 - Looking forward to working with PAWR testbeds and other future testbeds.

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