Intel Automotive Telematics Roadmap And The Path To 5G Connected Cars

Sierra Wireless

March 23rd, 2018

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Contents / Topics

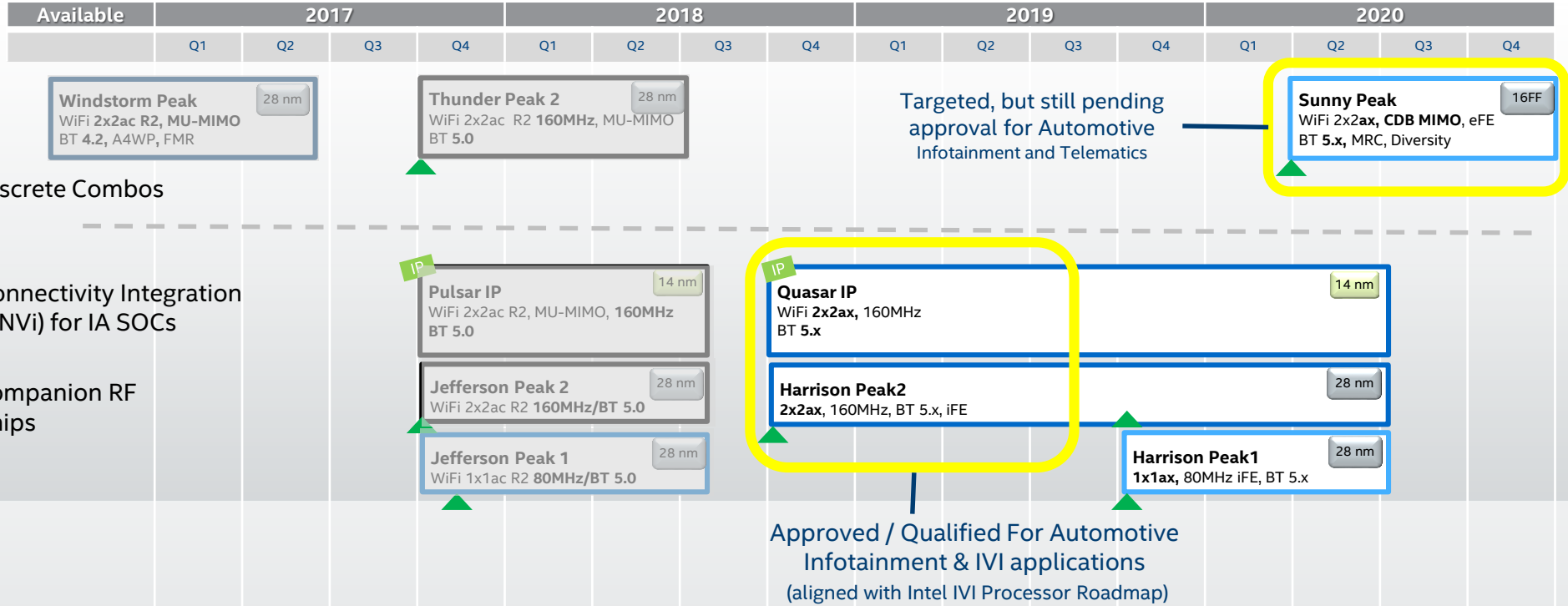
- Roadmap Overview: WiFi/BT & Cellular/Telematics
- XMM8162 Technical Overview
  - Modem and TCU System Architectures
  - GNSS Subsystem
  - RF Front End
  - KPIs
- Reference & Evaluation Platforms

Roadmap Update

Intel Connectivity Product Roadmap

Platform PRQ/PV at "▲"

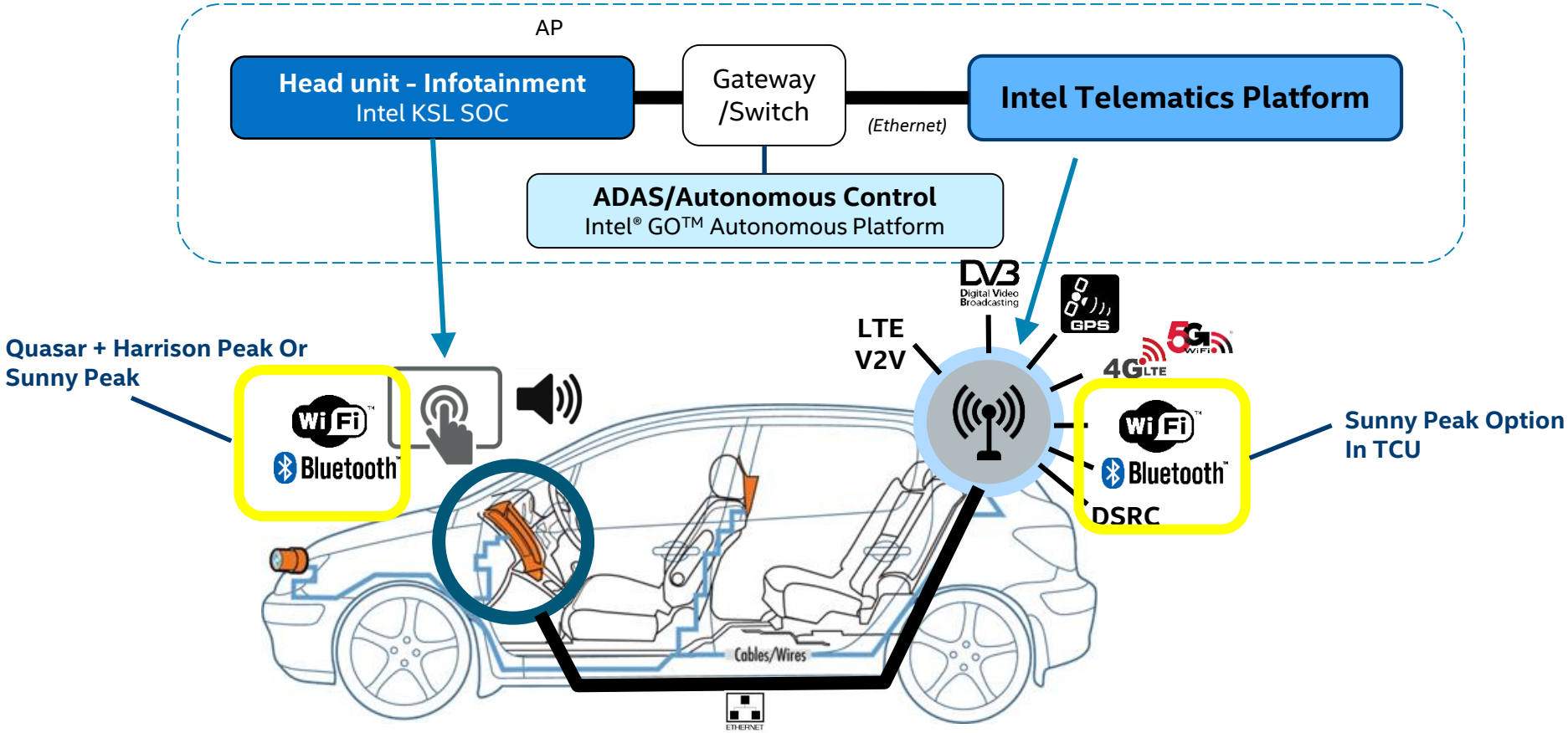
Last Updated: Mar 12, 2017



Available | In Development | In Planning | Idea

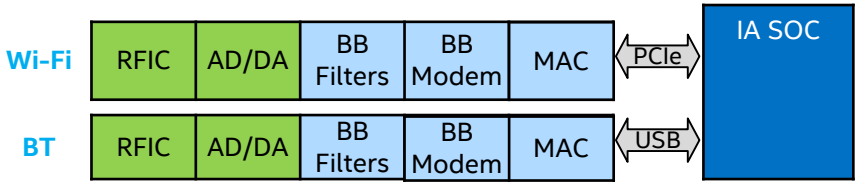
IP IP Block integrated in Intel SoC

Wireless Connectivity In The Vehicle



CNVi (WiFi/BT) High Level Overview

Current Discrete Only Design

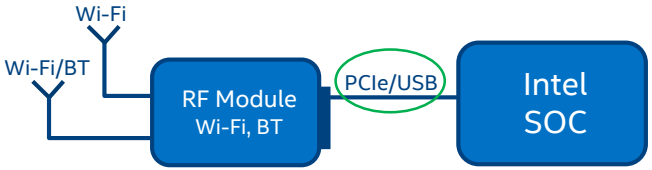


Discrete Modules

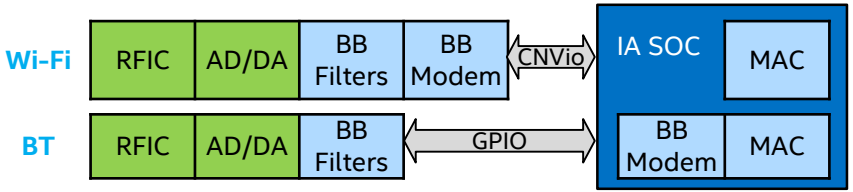
Windstorm Peak

Thunder Peak

Sunny Peak (for Auto)



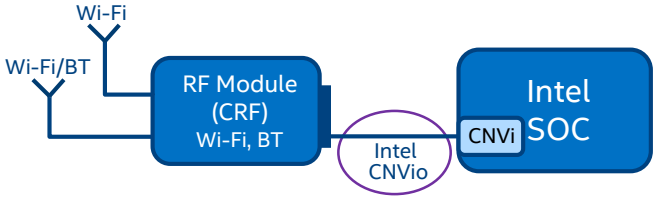
CNVi Design



Companion RF (CRF)

Jefferson Peak

Harrison Peak (for Auto)



Integrated MAC in the SoC/PCH saves cost and size

✓ Improved from previous generation
Module maker partnership

Intel® Wireless-AX 22560 (Harrison Peak)

WIRELESS TECHNOLOGIES

Wi-Fi
- ✓ 802.11ax Gigabit Wi-Fi (2.4Gbps)
- ✓ OFDMA
- ✓ 1024 QAM
- ▪ 160MHz Channel support
- ▪ Support for MU-MIMO Rx

BLUETOOTH*
- ✓ Support for BT5.1
  - ✓ LE Advertising Protection
  - ✓ Low Latency Reconnect
  - ✓ LE Power Control
- ✓ Runtime selection of USB/UART

PRODUCT POSITIONING

- 1st Gen 2x2 802.11ax (Pre standard)
- Lowest cost 11ax solution
- Increased network efficiency
- Better in dense environments
- High Performance consumer/business
- 2nd Gen integrated connectivity

OS

Win 10 | Linux | Chrome | Android

VALUE PROPOSITION

- ✓ 1st Gen 2x2 802.11ax (Pre standard)
  - ✓ Increased Network Efficiency
  - ✓ Better in Dense Environments
  - ✓ Up to 40% Higher Throughput
- ✓ Second Generation Integrated Connectivity (CNVi)
- ▪ Flexible routing with up to 10” between SOC and RF module
- ▪ Dynamic Regulatory Solution (DRS): Single worldwide SKU
- ✓ **Automotive grade SKU:**
  - ✓ AEC-Q100 Grade 3 (Target 2)
  - ✓ Extended Temp -40°C to +85°C (Target +105C)
  - ✓ Long life support

PLATFORMS

- ICL
- TGL
- **KSL**

SEGMENTS

Desktop | Mobile PC | Tablet | Automotive

HW CONFIGURATIONS

- M.2 2230 & 1216 SD & CoB
- **22x26 SD (TBD) Automotive**

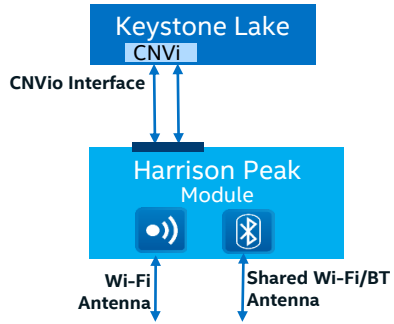
Product Brief

Coming Soon

AVAILABILITY & SCHEDULES

Commercial - 2H’18 (ICL)
Automotive – 1Q19 (KSL) Target

SYSTEM BLOCK DIAGRAM



MAIN KPI - Target

Wi-Fi
- TCP Max Tx/Rx TPT: 1.7Gbps
- Power consumption:
  - Idle Associated: 4.3mW
  - Video Streaming: 27mW

BLUETOOTH*
- Max Tx/Rx TPT: 1350 Kbps
- Power consumption:
  - BT Idle: 1.8mW
  - BT Connected Idle: 25mW
  - A2DP Playback: 62mW

Intel® Wireless-AX 22260 (Sunny Peak)

✓ Improved from previous generation
Module maker partnership

Pending POR Approval / Funding For Automotive

WIRELESS TECHNOLOGIES

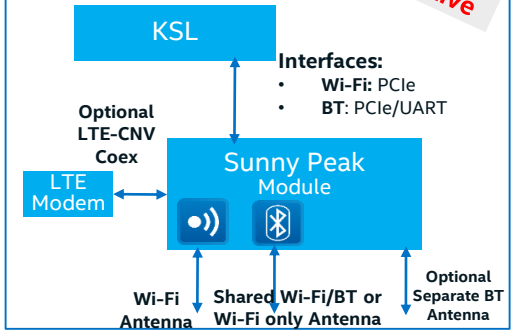
Wi-Fi
- ✓ 2x2 802.11ax, R2 ready, 80MHz
  - ✓ OFDMA
  - ✓ 1024 QAM
  - ✓ Dual band MCS11
- ✓ CDB MIMO, HE HB/80MHz + HE LB/20MHz
- ✓ Dual band listen radio– LP scan, ZWDFS
- ✓ Accurate Indoor location (11mc, 11az HW ready)
- ✓ 802.11p HW ready
- ✓ MF-PCIe Gen2, Single Lane WiFi/BT shared

BLUETOOTH
- ✓ Bluetooth 5.x
  - ✓ BLE 2Mbps, BLE Long Range, Advertising Extensions, Low Latency Reconnections
  - ✓ LE Audio, LP A2DP
  - ✓ BT MRC, TX Beamforming, TX Diversity, dedicated BT port
  - ✓ Interface options: MF-PCIe, USB, UART+I2S

VALUE PROPOSITION

- ✓ 802.11ax R2 ready Gigabit Wi-Fi – 1.488Gbps PHY
- ✓ High performance, small form factor device
- ✓ CDB- Concurrent Dual Band MIMO for multi-channel usages
- ✓ Dual band listen radio for background scanning and ZWDFS
- ✓ BT 2nd radio for MRV / Diversity / BF, Separate BT antenna option
- ✓ Tightly integrated WLAN/BT/5G Coex with XMM™80(1)60
- ✓ RAM-based firmware in WiFi/BT/Coex cores
- ✓ **Automotive grade (Auto SKU):**
  - ✓ AEC-Q100 Grade 2 (Target)
  - ✓ Extended Temp range -40°C to +105°C
  - ✓ Long life support

SYSTEM BLOCK DIAGRAM



PRODUCT POSITIONING

- 2x2 802.11ax R2 ready
- BT 5.x
- Best KPIs with eFEM
- New usages with CDB MIMO

PLATFORMS

- ADL/TGL
- Orrfield
- KSL-R

HW CONFIGURATIONS

- M.2 2230
- TBD – WLCSP, Ball pitch 0.3mm
- **Automotive grade module (size TBD)**

MAIN KPI - Target

Wi-Fi
- TCP Max Tx/Rx TPT: 1.3Gbps
- Power consumption:
  - Idle Associated: TBD
  - Video Streaming: TBD

BLUETOOTH*
- Power consumption:
  - BT Idle: TBD
  - BT Connected Idle: TBD
  - A2DP Playback: TBD

OS

Win 10 | Linux | Chrome | Android

SEGMENTS

Desktop | Mobile PC | SP | Automotive

Product Brief

Coming Soon

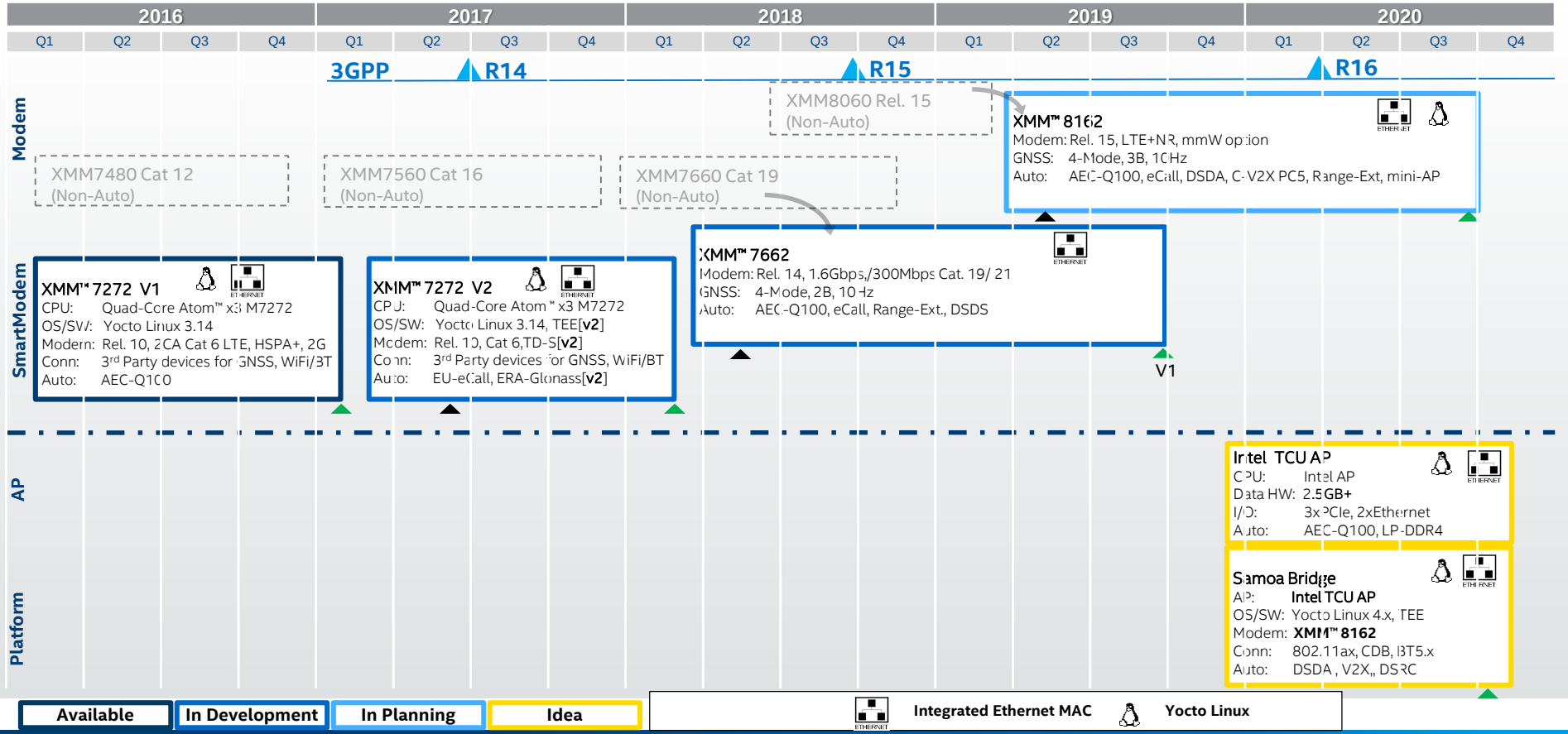
AVAILABILITY & SCHEDULES

H2 '20 Volume ramp

Automotive Telematics Roadmap

Version: V1.36
14 Mar'18

PV at ▲ Early Customer Sample ▲ 3GPP ASN.1 Freeze ▲

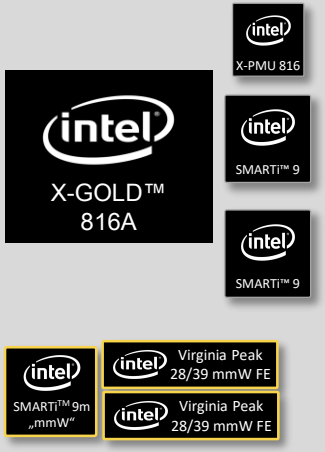


INTEL® XMM™ 8162

REL.15 5G CAPABLE WITH DSDA, C-V2X & MMW FOR AUTOMOTIVE MARKET

Value Proposition

XMM™ 8162 Platform

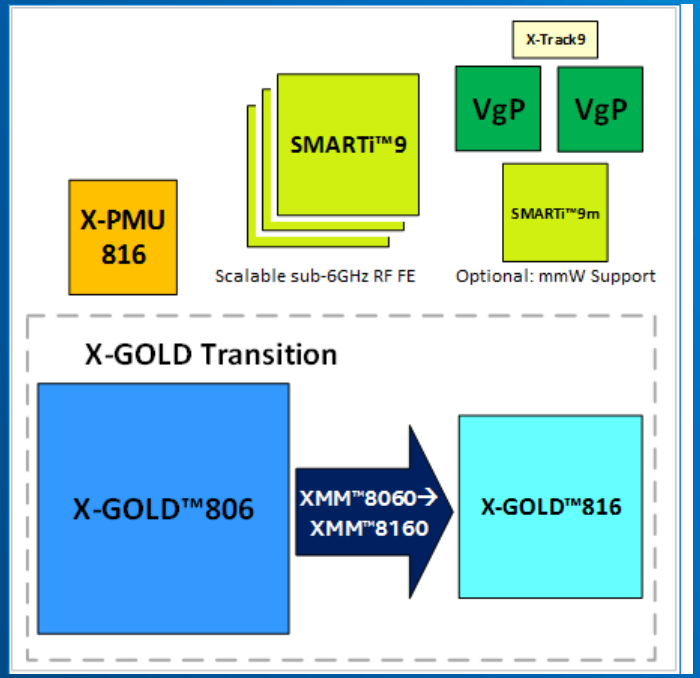


- Release 15 capable cellular modem for Automotive market, SA & NSA modes
- Modem Options with XMM™ 8162:
  - NR: Downlink : up to 6.0 Gbps, uplink: up to 3Gbps
- Cellular-V2X support: V2V/V2I/V2P (PC5), V2C (Uu), SC-PTM, eMBMS
- Integrated Ethernet MAC allows flexible placement of cellular Module
- Int. GNSS: GPS, GLONASS, Beidou, Galileo, QZSS, SBAS, L1/L2/L5, 10Hz
- Option for mmW support with SMARTi 9m and Virginia Peak ICs
- Innovative Automotive Features, Dual SIM Dual Active , Ethernet MAC
- Fastest Migration to 5G - Modular system allowing fast upgrade from XMM™ 7662
- Long Life Product Availability, Extended Temperature Range & AEC-Q100 Quality

INTEL'S 5GNR XMM™8060/XMM™8160 ONE FAMILY APPROACH

EASE OF MIGRATION FROM 8060 TO 8160

- XMM™8060/™8160 lays foundation for a converged platform and mmW RF
- Architecture scales for multiple generations
- Same architecture + RF for both: Merely Baseband transition X-GOLD™806 to X-GOLD™816.
- XMM™8060: accelerated time-to-market for SW & validation acceleration and re-use gain for XMM™8160
- XMM™8160 for System KPIs optimization (Power, Performance, PCB space) + addtl. features



Intel® XMM™ 816x with Mini-AP

Technical Product Overview

Chipset Features/Characteristics

System Integration Options

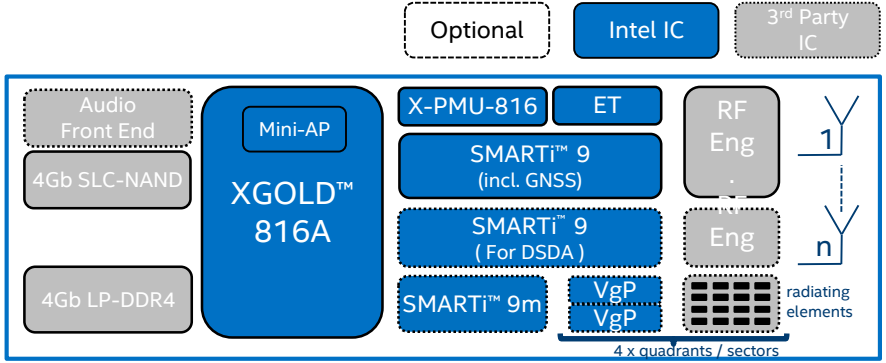
- Auto: Infotainment: Keystonelake
- Auto: Telematics: Samoa Bridge, 3rd Party APs

Modem and Wireless Connectivity

- 3GPP Rel.15 New Radio (NR) & LTE, NSA (Mode3), SA (Mode2)
- 6-mode Modem: 5G-NR, LTE-FDD, LTE-TDD,TD-SCDMA,DC-HSPA+,2G
- DL-NR: 6Gbit/s[1] ; sub6: 200MHz,256QAM ; mmW: 800MHz,64QAM ;
- UL-NR: 3Gbit/s ; sub6: 200MHz,256QAM; mmW: 400MHz, 64QAM ;
- LTE DL 2Gbps, UL 300Mbps ; VoLTE (IR.92) with SRVCC, CSFB ;
- **Coverage Extension - non BL UE with Mode A / B**
- **GNSS: GPS, GLONASS, Beidou, Galileo, QZSS, SBAS, L1 / 2 / 5, 10Hz**
- **Highly accurate differential GNSS, running on Host**
- **Dual SIM Dual Active (DSDA) SIM1: Any-RAT / SIM2: Any-RAT**
- 4x4 DL MIMO; 2x2 UL MIMO (NR);
- eLAA; FD-MIMO Class B, Latency Reduction
- mmW: 28/39GHz via companion ICs (SMARTi9m, Virginia Peak)
- **C-V2X: V2V/V2I/V2P (PC5), V2C (Uu), SC-PTM, MB-SFN(eMBMS)**
- 5G NR Bands: 3.3-4.2GHz, 4.4-4.99GHz, LTE re-farming

Other Key Automotive Features

- **ITU-T P.1100 and P.1110 enablement, AEC-Q100 Silicon (Level 3)**
- **Extended Temp: -40C to +110C[2] T-junction, 105C Crystal (PCB 1mm)**
- **Emergency Call: EU eCall, ERA Glonass, NG-eCall, A.C.N**



Mini-AP

- **Cortex A5, 840MHz, 1300DMIPs**
- **Yocto Linux, LTS Kernel**
- **H/W accelerated NAT Routing & VLAN tagging**
- **Fast & Secure Boot, Secure Storage, DRNG**

Key interfaces

- 1 x PCIe Gen4 or **Ethernet MAC, up to 10Gbps (XFI /SGMII / OC-SGMII)**
- 2 x I2S for Digital Audio ;
- 3 x USIF Interfaces (UART up to 5Mbit/s, SPI up to 100Mbit/s)
- 2 x USIM ;
- 1 x USB2.0 ULPI (External PHY required) ; 1 x I2C
- ADC, 10+ GPIOs ;
- SLC NAND, Serial-NOR, LP-DDR4

[1] achievement of peak data rate requires mmWave support

[2] Best Effort up to 125C – 2.5C temperature sensor tolerance.

XMM Modem SKU Overview

Platform Key Cellular Feature	XMM 8162 Premium	XMM 8162 High	XMM 7662 Premium	XMM 7662 High	XMM 7662 Mid	XMM 7662 Low	XMM 7662 Cat. 6
mini-AP option	Option	Option	-	-	Note1	Note1	Note1
New Radio NSA / SA Mode	Yes	Yes	-	-	-	-	-
Maximum DL Category (Speed)	(6000Mbps)	(4000Mbps)	Cat. 19 (1600Mbps)	Cat. 16 (1000Mbps)	Cat. 12 (600Mbps)	Cat. 9 (450Mbps)	Cat. 6 (300Mbps)
Maximum UL Category (Speed)	(3000Mbps)	(2000Mbps)	Cat. 21 (300Mbps)	-	-	-	-
Dual SIM	See Options (DSDA & DSDS)	See Options (DSDA & DSDS)	See Options (DSDS)	See Options (DSDS)	See Options (DSDS)	See Options (DSDS)	-
C-V2X PC5	See Options	See Options	-	-	-	-	-
DL 4x4 MIMO	Yes	Yes	Yes	Yes	-	-	-
600MHz (Band 71)	Yes	Yes	Yes	Yes	Yes	Yes	-
V2x: SC-PTM	Yes	Yes	Yes	Yes	Yes	Yes	-
Range Extender (Rel. 14)	Yes	Yes	Yes	Yes	Yes	Yes	-
GNSS	See Options 10Hz, L1	See Options 10Hz, L1	See Options 10Hz, L1	See Options 10Hz, L1	10Hz, L1	10Hz, L1	1Hz, L1
DL 2x2 MIMO	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HSPA+	42Mbps	42Mbps	42Mbps	42Mbps	42Mbps	42Mbps	42Mbps
WCDMA, TD-SCDMA, GSM	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Other 8162 SKUs are under investigation.
Note1: investigation to enable embedded software application at lower speed SKUs.

Future Flexibility & Scalability

potential TRX Configurations within XMM™ 8162

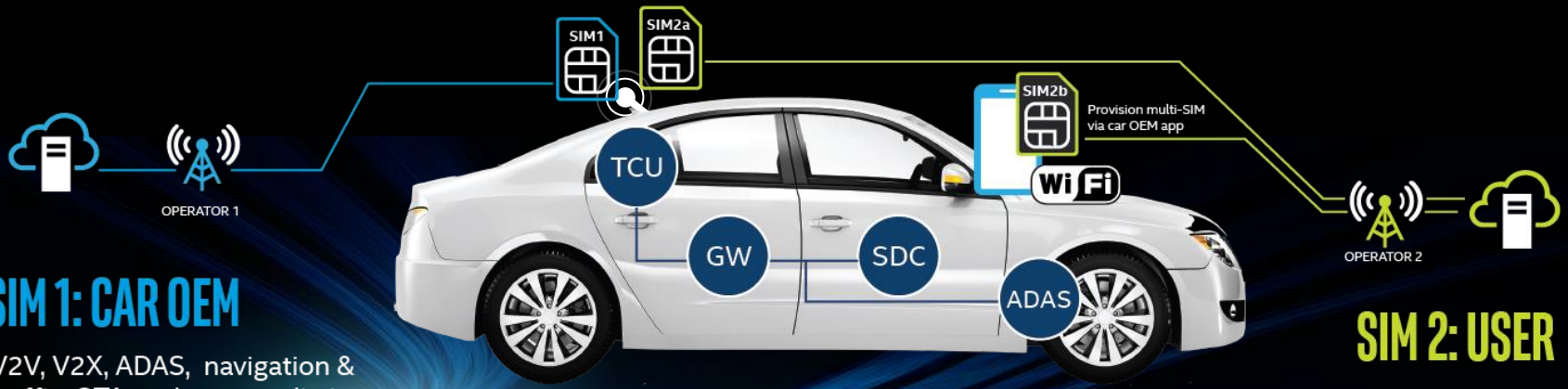
		1x SMARTi 9	2x SMARTi 9	3x SMARTi 9	Comment
Single SIM	NR-SA	Yes			
	NR-SA + PC5	Yes			Most Cost sensitive offering if PC5 mandated
	NR-NSA	Yes			
	NR-NSA + PC5		Yes		
Dual SIM	NR-NSA + NR-SA		Yes		
	NR-NSA + NR-NSA		Yes		
	NR-NSA + NR-SA + PC5		Yes		Maximum of NR-SA or LTE on Modem with PC5 support.
	NR-NSA + NR-NSA + PC5			Yes	Super set solution with maximium future flexibility, dedicating one S9 to PC5 sidelink

Priority configuration needs to be aligned with Customer
mmWave configuration are not shown on this table, but can only exist with 1 or 2 SMARTi 9 configurations

XMM™ 8162 Update

DUAL SIM | OEM + USER

Dual SIM for the auto manufacturer and the user provide optimized performance, while segmenting and prioritizing data traffic.



SIM 1: CAR OEM

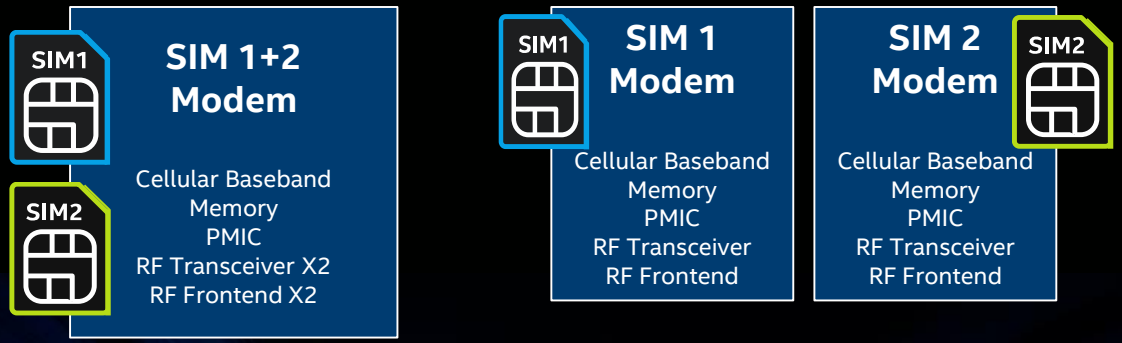
V2V, V2X, ADAS, navigation & traffic, OTA updates, predictive maintenance, insurance, concierge services.

SIM 2: USER

HD infotainment, Wi-Fi hotspot, Wi-Fi voice (ePDG), HD voice calls. 2A=in-car, 2B=mobile device

DUAL SIM | SINGLE MODEM

DSDA, delivered with a single modem,
offers significant benefits for both car OEMs and drivers.



TECHNICAL BENEFITS

- Offers a smaller form factor, with a clear path to 5G
- Delivers PCB area & cost savings, simplified routing /shielding
- Reduces system components & overall bill of materials
- Utilizes less power in most use cases, as compared to dual modem

USER BENEFITS

- Delivers high-speed, high-performance car & user connectivity
- Separates & prioritizes car & user data and traffic
- Utilizes existing cellular contract & phone number
- Provides access to external antenna for improved performance

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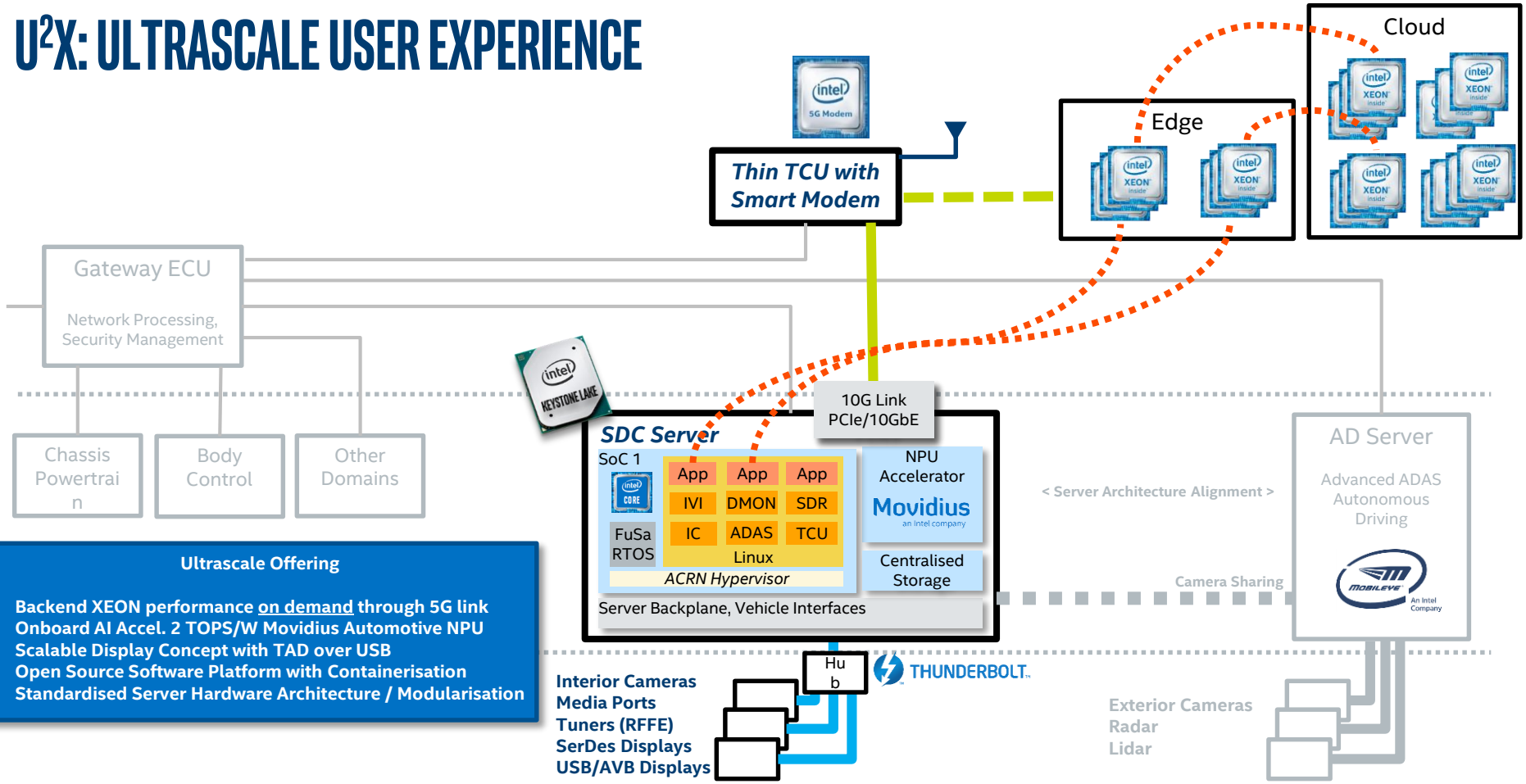
XMM8162 & TCU Architectures

- Thin TCU with embedded Cortex A5 in cellular
- Embedded Yocto Linux
- TCU SW virtualized in SDC compute cluster

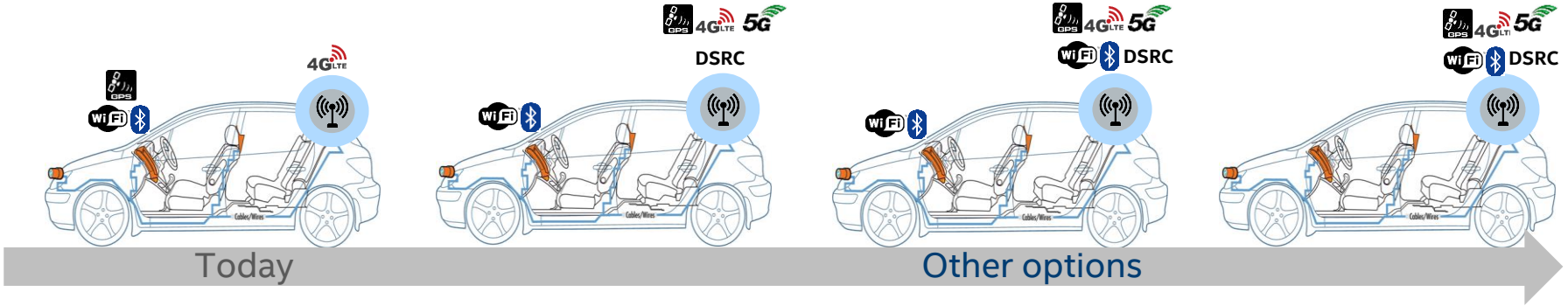
U²X: ULTRASCALE USER EXPERIENCE



Ultrascale Offering

- **Backend XEON performance on demand through 5G link**
- **Onboard AI Accel. 2 TOPS/W Movidius Automotive NPU**
- **Scalable Display Concept with TAD over USB**
- **Open Source Software Platform with Containerisation**
- **Standardised Server Hardware Architecture / Modularisation**

Market Environment → **Connectivity**



	IVI	TCU
Cellular usages		V2N
Wi-Fi/BT Usages	1. Phone connect (e.g. Car Play) 2. Provide Wi-Fi Hotspot	N/A

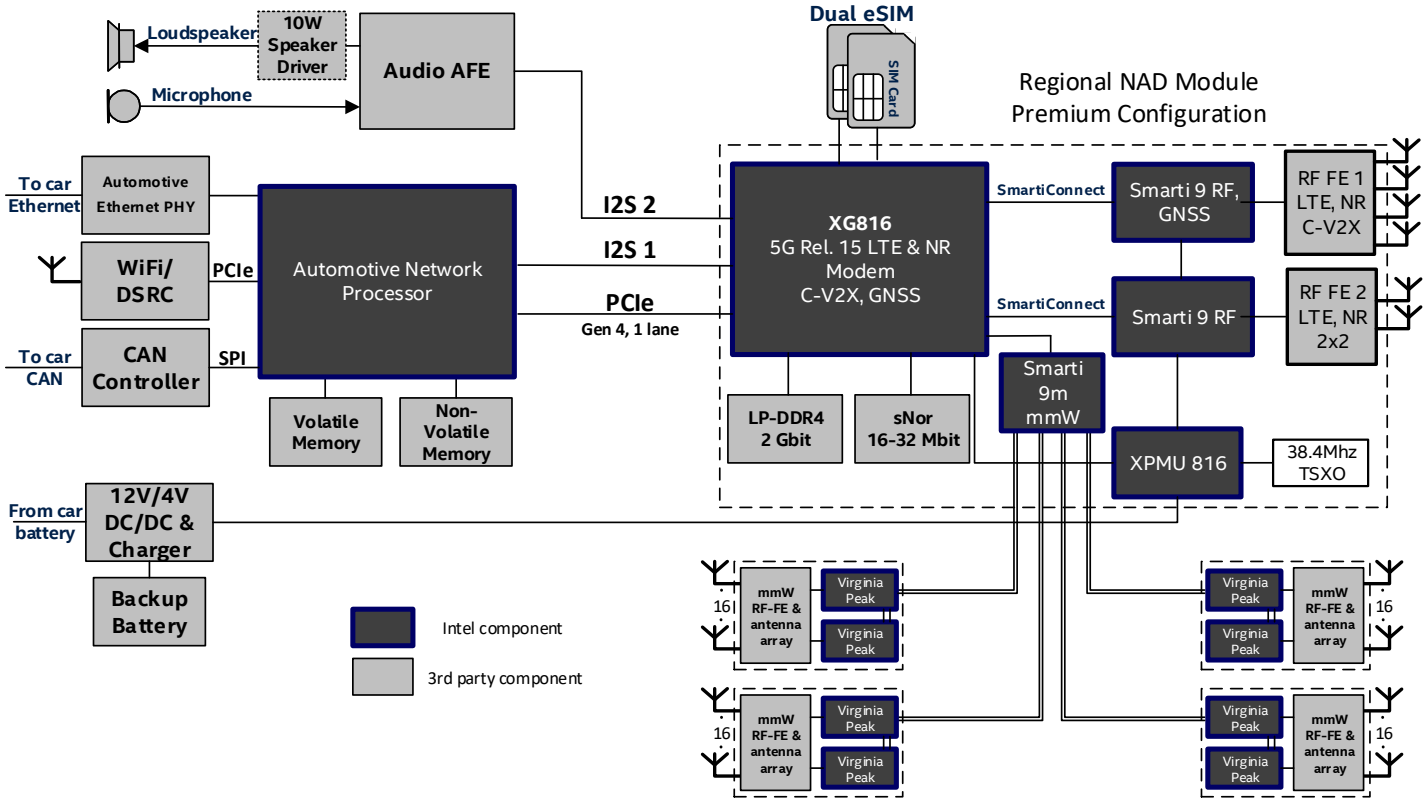
IVI	TCU
	V2N, V2I, V2V, V2P
1. Phone connect (e.g. Car Play) 2. Provide Wi-Fi Hotspot **or** Connect to Access point(s)	1. V2V or (DSRC)

IVI	TCU
	V2N, V2I, V2V, V2P
Phone connect (e.g. Car Play)	1. Connect to Access point(s) 2. Provide Wi-Fi hotspot 3. V2V (DSRC)

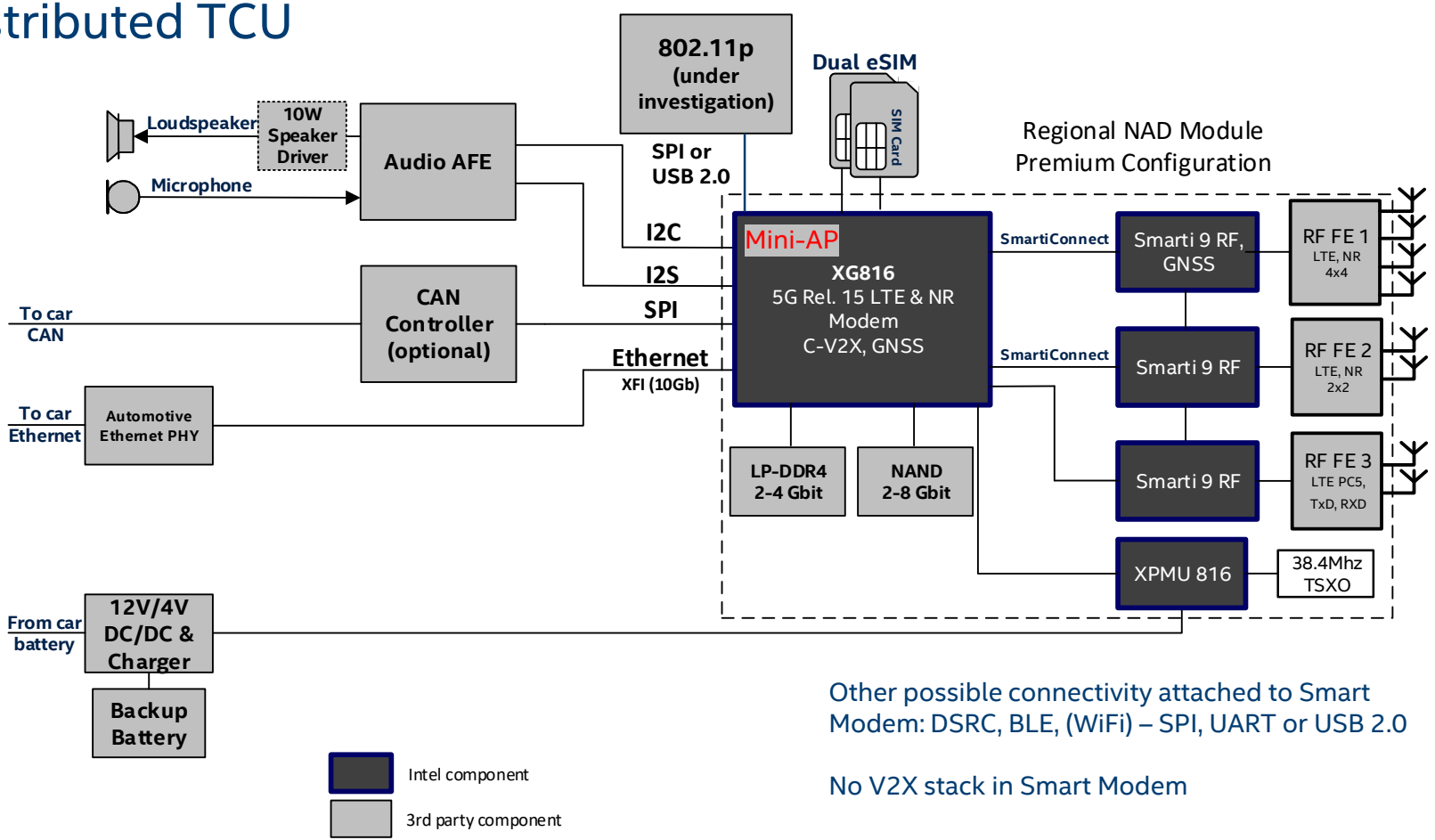
IVI	TCU
	V2N, V2I, V2V, V2P
N/A	1. Phone connect 2. Connect to Access point(s) 3. Provide Wi-Fi hotspot 4. V2V (DSRC)

Different models emerging for how to partition capabilities among the Telematics Control Unit and Infotainment head unit

Self-Contained TCU – AP + Modem + CNV



Distributed TCU



Other possible connectivity attached to Smart Modem: DSRC, BLE, (WiFi) – SPI, UART or USB 2.0

No V2X stack in Smart Modem

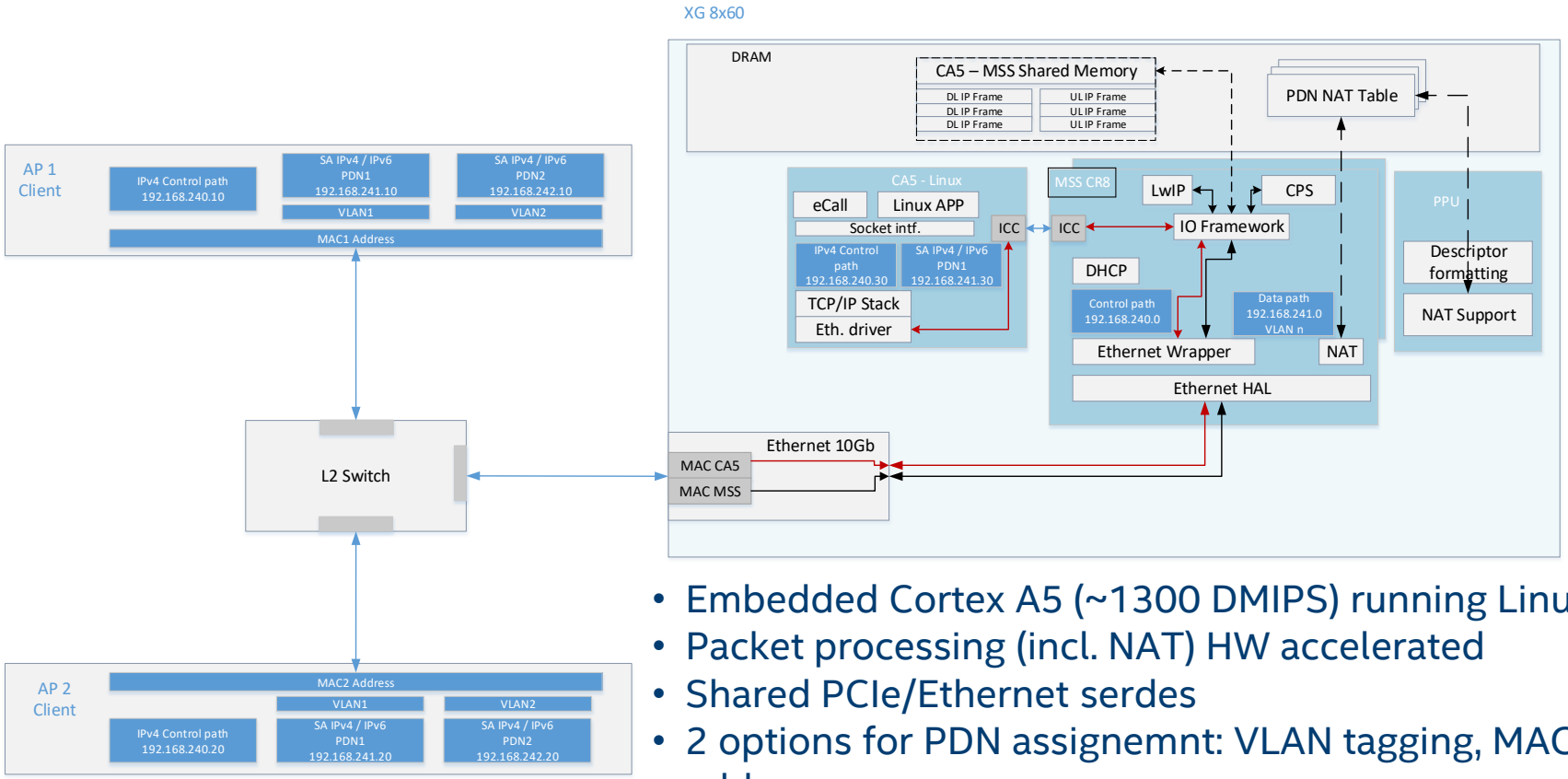
Comparison of Self-Contained V. Distributed TCU

	Self-contained TCU Local AP in TCU	Distributed TCU Compute cluster as TCU app server
System cost	AP + flash + DDR memory	~15-20$ BOM cost saving
Functional Safety	TCU needs to consider FuSa for V2X and potentially GNSS	FuSa relevant functions are moved out of TCU into other units that anyway need to be FuSa complianent (ASIL decomposition)
Development	TCU development w/o bigger dependencies	Needs tighter integration between compute cluster & TCU
Functionality	(strong) AP allows more functionality to be integrated into TCU	Requires to some extend distributed connectivity (maybe not bad wrt. cable length and antenna placement)
Security	Local AP needs to handle security aspects: firewall, intrusion detection etc.	Modem air interface provides a wide attack interface, modem must not directly be connected to safety critical ECUs, entity behind modem needs to shield
WiFi connectivity	Can be attached to AP, NAT in AP	Options: 1. placed in IVI; 2. connected with switch in TCU, 3. integrated in cellular modem (future), NAT in modem

SW Functions That Can Remain In TCU (XMM8162 „mini“ AP)

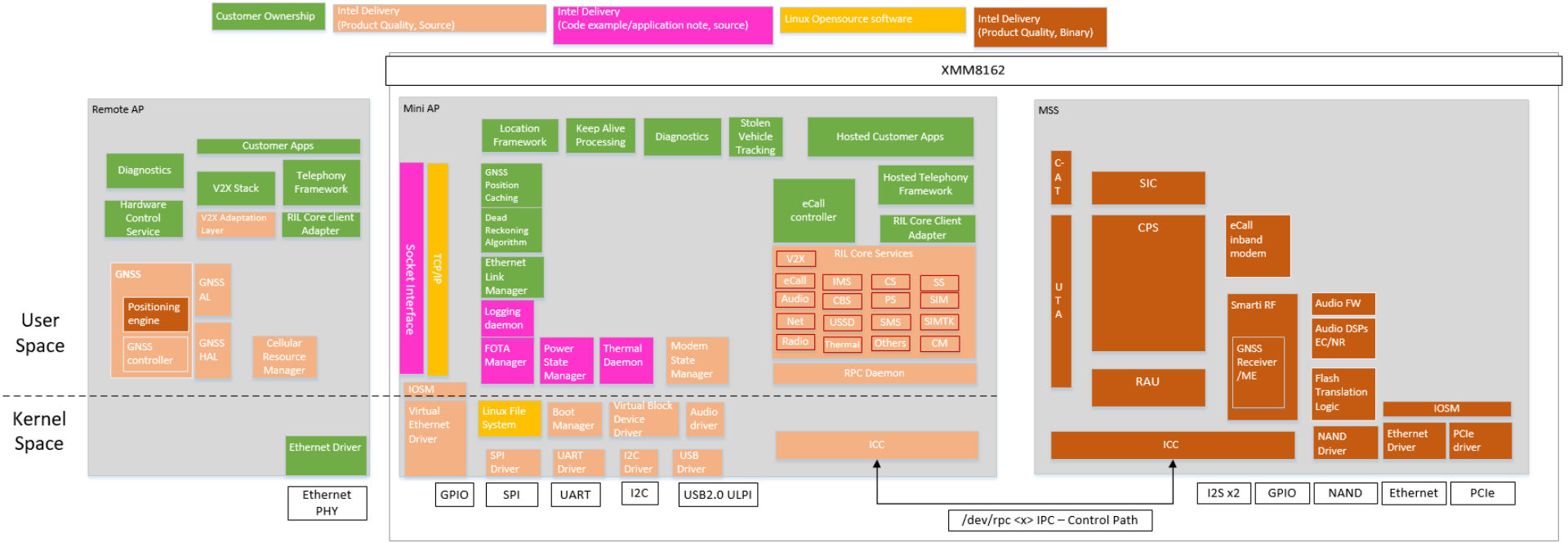
- **eCall** application (complete handling of eCalls, including call setup, MSD generation, priority handling, call termination ..., control of integrated AFE (via I2C))
- **GNSS** position fix & dead reckoning (for eCall & stolen vecicle tracking) → could be cached over car network
- **Keep alive** messaging possibly with secured link (sending regular keep alive messages to keep the IP connection active even if ignition is off and no data traffic)
- **Stolen Vehicle Tracking**
- **Diagnostics** - general feature for every electronics unit in the car, diagnostics happens at boot but can also be requested during operation by the OBD Unit (OBD = On-Board Diagnostics), classic or adaptive Autosar in Linux, communication/services with CAN controller
- **FOTA** update (remote and local)
- Optional: low speed **WiFi** chip with WiFi stack and DSRC with message forwarding
- Optional: connect **BLE** chip for car door opening
- Fast & secure **boot**

Smart Modem HW Architecture



- Embedded Cortex A5 (~1300 DMIPS) running Linux
- Packet processing (incl. NAT) HW accelerated
- Shared PCIe/Ethernet serdes
- 2 options for PDN assignemnt: VLAN tagging, MAC addresses

Smart Modem SW Architecture



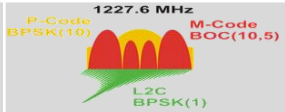
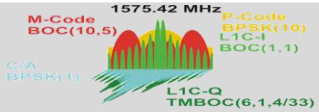
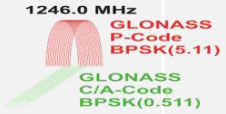
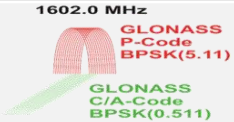
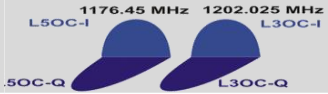
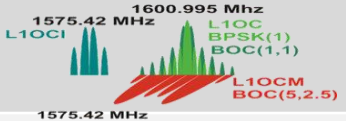
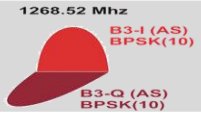
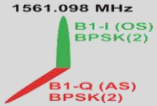
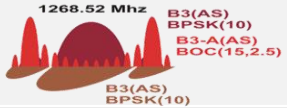
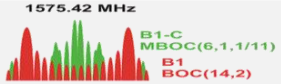
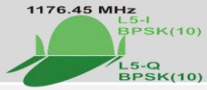
Contents / Topics

- Roadmap Overview: WiFi/BT & Cellular/Telematics
- XMM8162 Technical Overview
  - Modem and TCU System Architectures
  - GNSS Subsystem
  - RF Front End
  - KPIs
- Reference & Evaluation Platforms

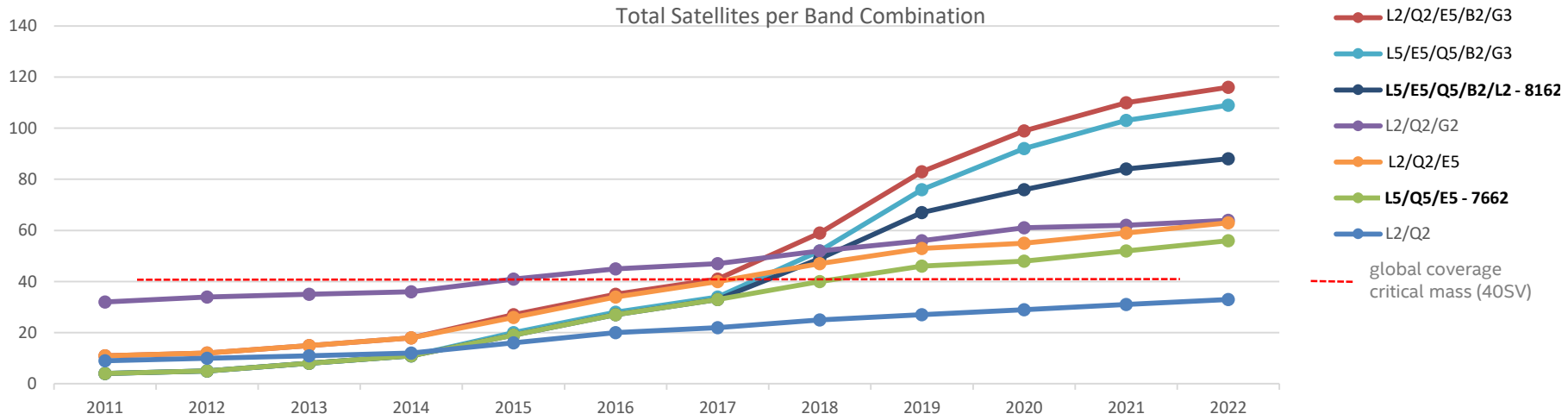
GNSS Topics

- Multi Band GNSS
- GNSS in XMM™ 7662
- GNSS in XMM™ 8162

Muti Band GNSS - Intro

GNSS Bands	L5 / E5 / B2	L2	B3 / E6	L1 / E1 / B1
GPS				
Glonass FDMA				
Glonass CDMA				
Galileo				
BDS II				
BDS III				
QZSS				
IRNSS				

Multi-Band GNSS Potential Support

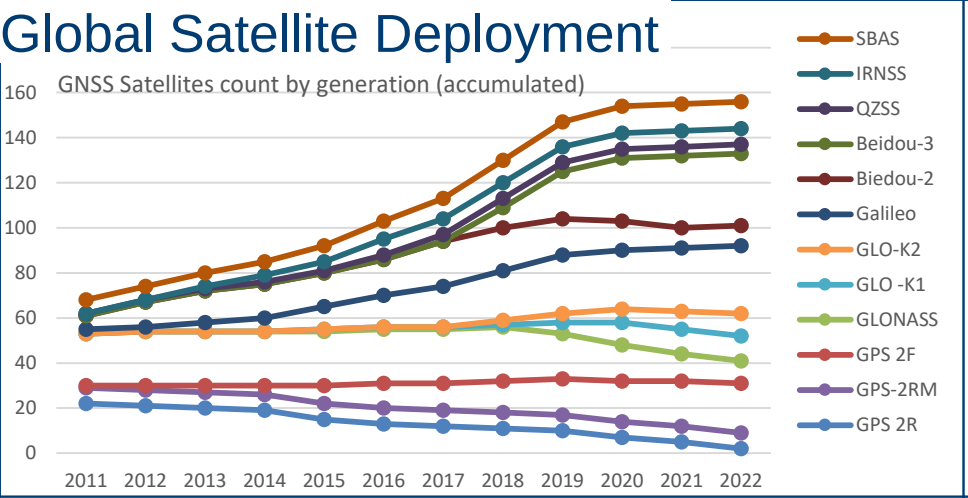


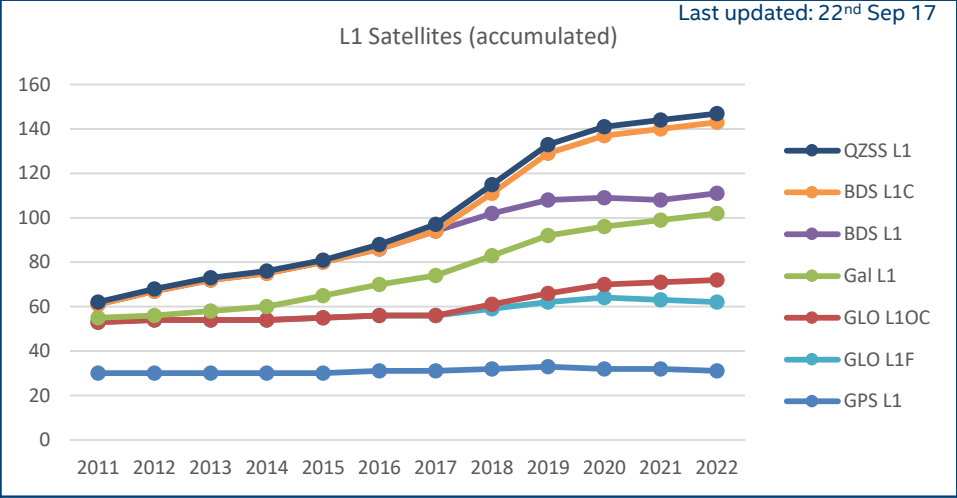
- On 2020 both L2, L5 or L2/E5b combinations will support 50-60 satellites which should provide good global coverage
- L5 signal characteristics should enable better performance on the L5 combination comparing to L2
- Glonass L2 (G2 on purple line above) is considered to be less reliable than GPS/Galileo signals
- Looking forward, introduction of Beidou B2a, B2b and Glonass G3OC signals on L5 will increase reliable satellites count to above 100

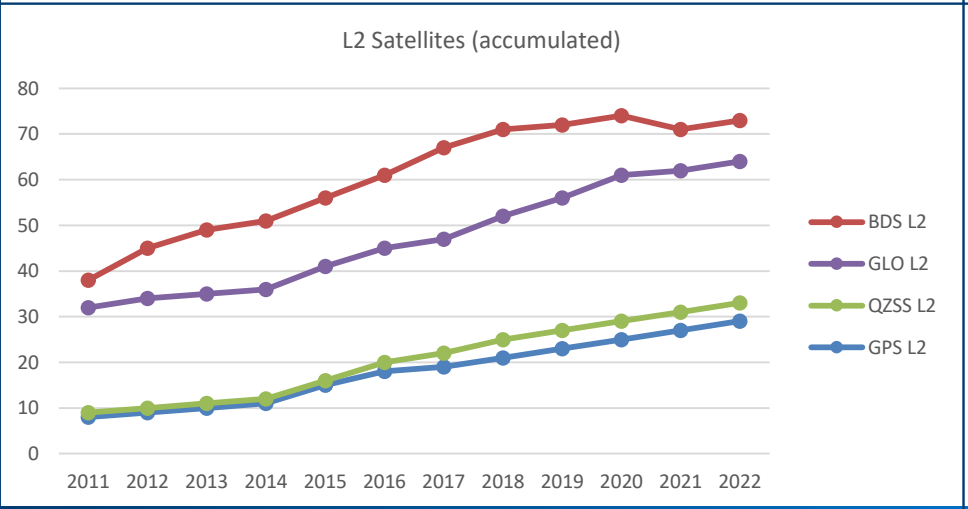
Bottom Line: L5 vs L2/E5b are expected to deliver comparable performance with minor performance advantage in favor of L5 vs minor coverage advantage for L2/E5b – but coverage is not expected to be an issue by 2020

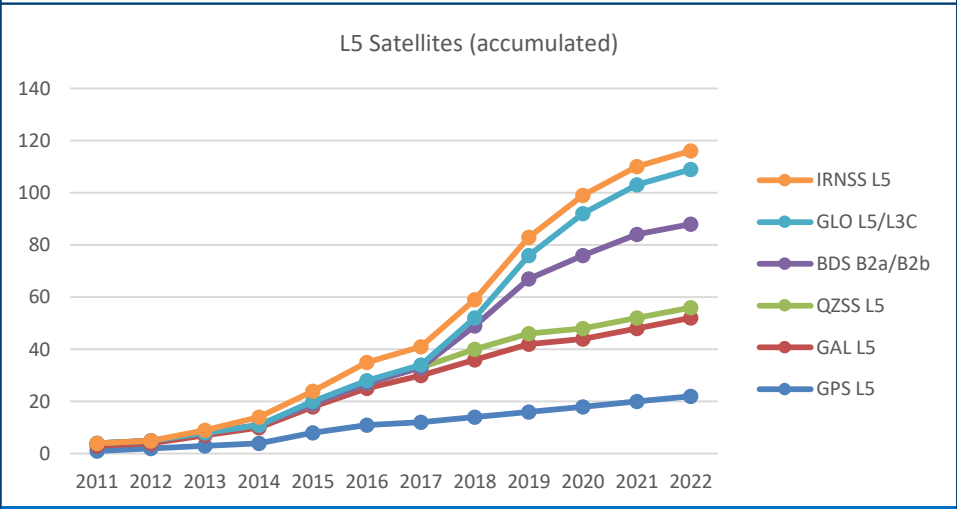
Global Satellite Deployment

Last updated: 22nd Sep 17









Comparison of GPS L2C vs.L5

Item	L2C	L5	Comment
Carrier Frequency	1227.60 MHz	1176.45 MHz	L5 in highly protected Aeronautical Radio Navigation Services (ARNS) radio band
Modulation	BPSK(1)	BPSK(10)	
Bandwidth (Null to Null)	2.046MHz	20.46MHz	L5 has greater bandwidth for improved jam resistance and x10 better autocorrelation accuracy
Code Frequency	Data 511.5KHz Pilot 511.5KHz	10.23MHz	
Primary PRN Code Length	Data: 10,230 (20ms) Pilot: 767,250 (1.5s)	Data: 10230 (1ms) Pilot: 10230 (1ms)	
Secondary PRN Code Length	n/a	Data: 10 Pilot: 20	
Minimum Received Power Signal Levels	Block II/IIA/IIR Satellites: -134.5 dBm Block IIR-M Satellites: -131.5 dBm Block IIF Satellites: -131.5 dBm	-127.9 dBm	L5 at least 3.6dBm stronger than L2C

GNSS XMM™ 7662 Section

GNSS in XMM™ 7662

Featureset

GNSS

- GPS L1, L5
- QZSS L1, L5
- Galileo E1, E5
- GLONASS L1
- Beidou B1
- SBAS - WAAS, EGNOS, MSAS, GAGAN, SDCM
- Server Based Ext. Ephemeris
- Context awareness (external context)
- Sensors Fusion
- Host based Positioning Engine
- e911, eCall, ERA-Glonass support
- 10 Hz fix rate

OS SUPPORT

- Linux Yocto

VALUE PROPOSITION

- Leveraging on Dual Band to improve performance
  - Increased accuracy
  - Enhanced anti-jamming
  - Improved multi-path rejection
- Designed for coex with cellular modem
- State of the art sensors fusion and dead reckoning
- 3GPP Rel 14 certified
- Extended Temperature Range -40 ~ +95

PLATFORMS

XMM™ 7662

SEGMENTS

Auto

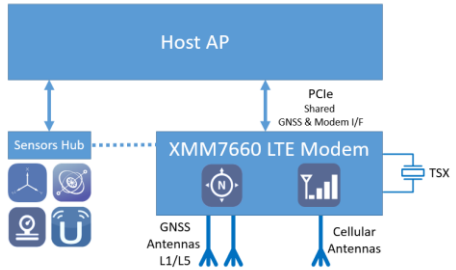
HW FEATURES

- Integrated in SMARTi™ 8 RFIC
- 28nm HPC+ process
- PCIe Host I/F (shared)

AVAILABILITY & SCHEDULE

Aligned with XMM™ 7662

SYSTEM BLOCK DIAGRAM



MAIN KPIs

Acquisition Sensitivity: Hot Start	-157 dBm
Tracking Sensitivity: Static - GNSS	-160 dBm
Tracking Sensitivity: Driving - GNSS	-160 dBm
TTFF: hot start @ -130 dBm - GNSS	1 Sec
TTFF: hot start @ -142 dBm - GNSS	2 Sec
GNSS Static Horizontal Accuracy @ -130 dBm	2m
GNSS Static Hrztl Accuracy L1/L5 @ -130 dBm	<1m

GNSS XMM™ 8162 Section

GNSS in XMM™ 8162

Featureset

GNSS

- GPS L1, L2, L5
- QZSS L1, L2, L5
- Galileo E1, E5
- Beidou III B1, B2
- GLONASS L1
- SBAS - WAAS, EGNOS, MSAS, GAGAN, SDCM
- Server Based Ext. Ephemeris
- Context awareness (external context)
- Sensors Fusion
- Host based Positioning Engine
- e911, eCall, ERA-Glonass support
- 10 Hz fix rate
- Supporting 3rd party RTK/PPP

OS SUPPORT

- Linux Yocto

VALUE PROPOSITION

- Leveraging on Triple Band to improve performance over Dual Band receiver performance
  - Increased accuracy
  - Enhanced anti-jamming
  - Improved multi-path rejection
- Designed for coex with cellular modem
- State of the art sensors fusion and dead reckoning
- 3GPP Rel 15 certified
- Extended Temperature Range -40 ~ +95

PLATFORMS

XMM™ 8162

SEGMENTS

Auto

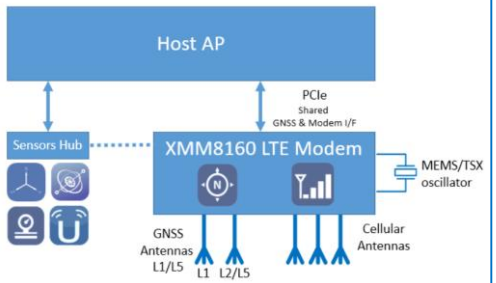
HW FEATURES

- Integrated in SMARTi™ 9 RFIC
- 16nm FF process
- PCIe Host I/F (shared)

AVAILABILITY & SCHEDULE

Aligned with XMM™ 8162

SYSTEM BLOCK DIAGRAM



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GNSS Static Hrztl Accuracy SB @ -130 dBm	2m
GNSS Static Hrztl Accuracy MB @ -130 dBm	<1m

XMM™ 8162 / 7662 GNSS Feature comparison table

	XMM™ 7662	XMM™ 8162
Constellations	Concurrent GPS, Glonass, Beidou, Galileo & QZSS	Concurrent GPS, Glonass, Beidou, Galileo & QZSS
Multi band contellations supported	GPS L1/L5, QZSS L1/L5 Galileo E1/E5	GPS L1/**L2**/L5, QZSS L1/**L2**/L5 Galileo E1/E5 **BDS III B1/B2**
Concurrent band support	L1+L5	L1**+L2**+L5
GNSS Fix rate	Up to 10Hz	**>10Hz** with sensors fusion
SBAS support	Yes (including WAAS, EGNOS, MSAS, GAGAN, SDCM)	Yes (including WAAS, EGNOS, MSAS, GAGAN, SDCM)
Emergency call positioning	e911, eCall, ERA-Glonass	e911, eCall, ERA-Glonass
Certified assisted GNSS	3GPP Rel. 14 Control Plane, SUPL 2.0.2	**3GPP Rel. 15** Control Plane, SUPL 2.0.2
Extended Ephemeris	Yes (up to 14 days Extended Ephemeris for GPS, Glonass, Beidou, Galileo & QZSS)	Yes (up to 14 days Extended Ephemeris for GPS, Glonass, Beidou, Galileo & QZSS)
Support for Dead Reckoning	Yes	Yes
High Precision correction data support	No	**RTK/PPP from 3rd party**

XMM™ 8162 GNSS band support

Supported by Intel GNSS - 8162

	L5		L2	E6	L1
	E5a	***E5b***			
GPS	L5	-	L2C		L1C
Glonass	-	-	-		L1
Galileo	E5a	E5b	-	-	L1
Beidou II/III	B2a	B2b	-	-	B1/B1C
QZSS	L5	-	L2C		L1C
IRNSS	-	-			

Concurrent support of L1+L2+L5 band combination is confirmed in XMM™ 8162.

IRNSS is not Dual Band, L5 only, hence not planned in XMM™ 8162.

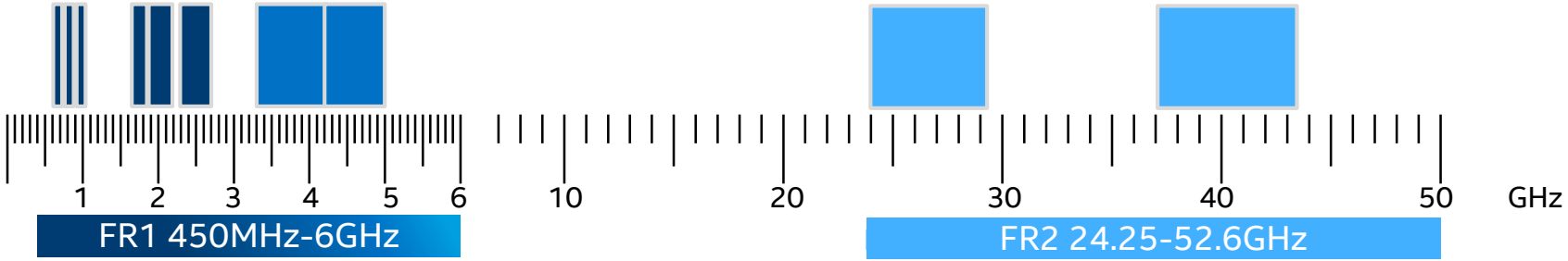
GLONASS L2 not supported due to band frequency offset.

Contents / Topics

- Roadmap Overview: WiFi/BT & Cellular/Telematics
- XMM8162 Technical Overview
  - Modem and TCU System Architectures
  - GNSS Subsystem
  - RF Front End
  - KPIs
- Reference & Evaluation Platforms

5G NR RF Overview

5G New Radio (NR) Bands in focus

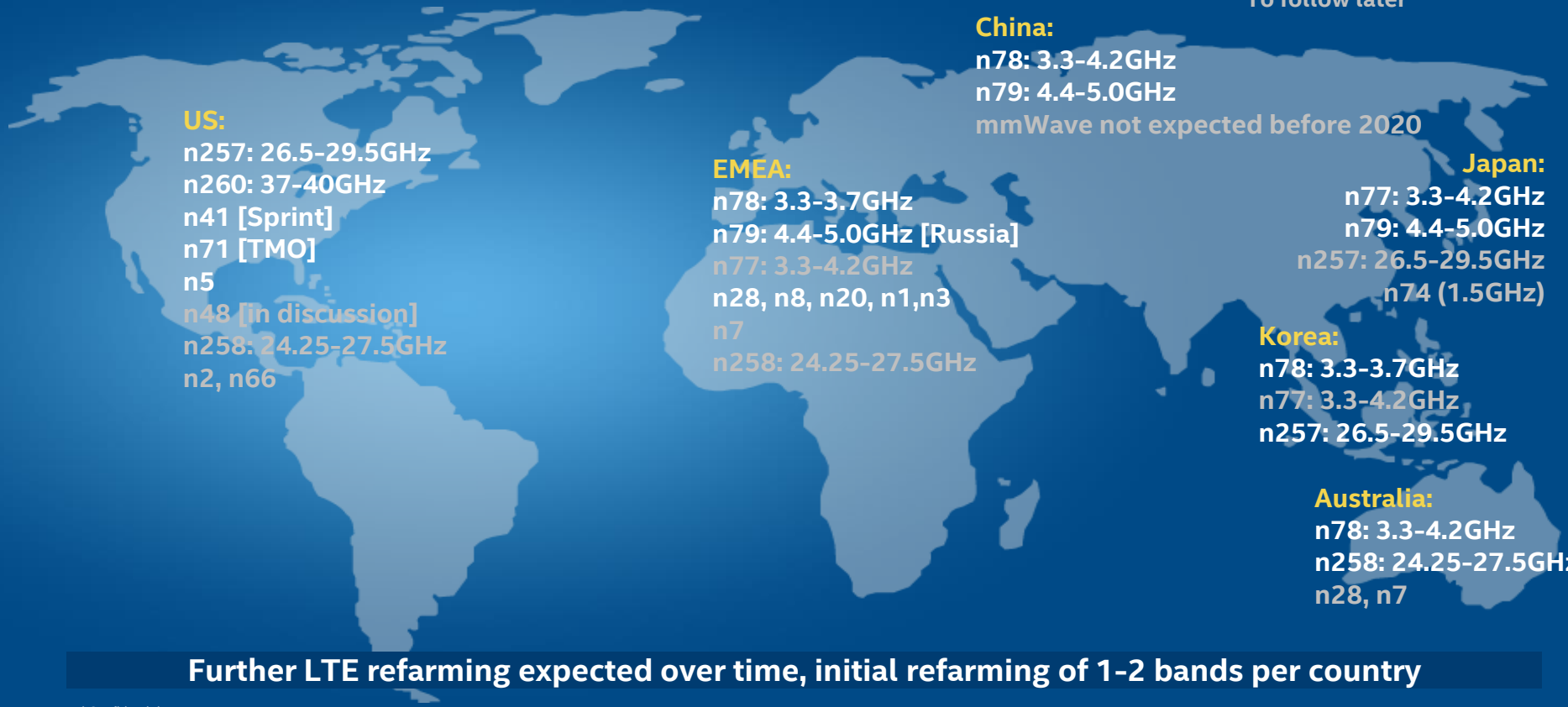


- **"LTE band re-farming" [n1,n2,n3,n4,n5,n7,n8,n20,n28,n38,n41,n66…]**
  - Re-farming of existing LTE spectrum to NR for geographic coverage and IoT applications
  - Many bands agreed within 3GPP as 5G re-farmed bands, others expected over time
  - Supplementary uplink bands also defined.
- **"sub 6 GHz NR" [n77,n78,n79]**
  - Wider bandwidth providing a trade-off for 5G applications that require both capacity and coverage
  - Expected in first wave of 5G deployments. Some overlap with LTE UHB bands (B42,43,48 etc)

- **"mmWave" [n257, n258, n260]**
  - Needed to accommodate very wide channel bandwidths for 5G applications requiring extremely high data rates
  - Requires mmWave antenna arrays

Last updated: 13 Mar 2018

Global 5G NR initial deployment bands expected



Initial 5G deployment bands
To follow later

US:
n257: 26.5-29.5GHz
n260: 37-40GHz
n41 [Sprint]
n71 [TMO]
n5
n48 [in discussion]
n258: 24.25-27.5GHz
n2, n66

China:
n78: 3.3-4.2GHz
n79: 4.4-5.0GHz
mmWave not expected before 2020

EMEA:
n78: 3.3-3.7GHz
n79: 4.4-5.0GHz [Russia]
n77: 3.3-4.2GHz
n28, n8, n20, n1,n3
n7
n258: 24.25-27.5GHz

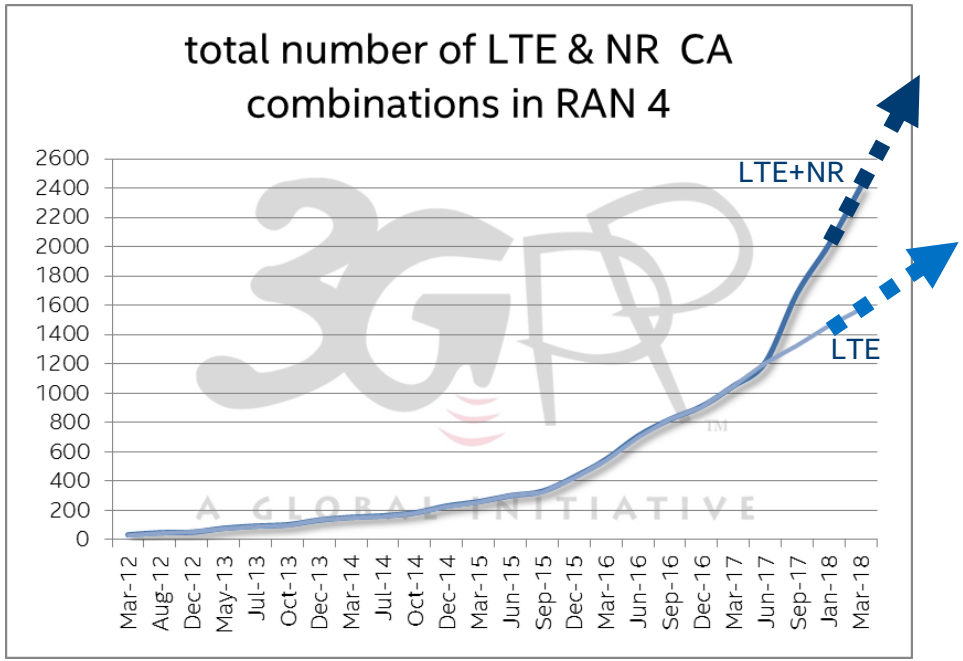
Japan:
n77: 3.3-4.2GHz
n79: 4.4-5.0GHz
n257: 26.5-29.5GHz
n74 (1.5GHz)

Korea:
n78: 3.3-3.7GHz
n77: 3.3-4.2GHz
n257: 26.5-29.5GHz

Australia:
n78: 3.3-4.2GHz
n258: 24.25-27.5GHz
n28, n7

Further LTE refarming expected over time, initial refarming of 1-2 bands per country

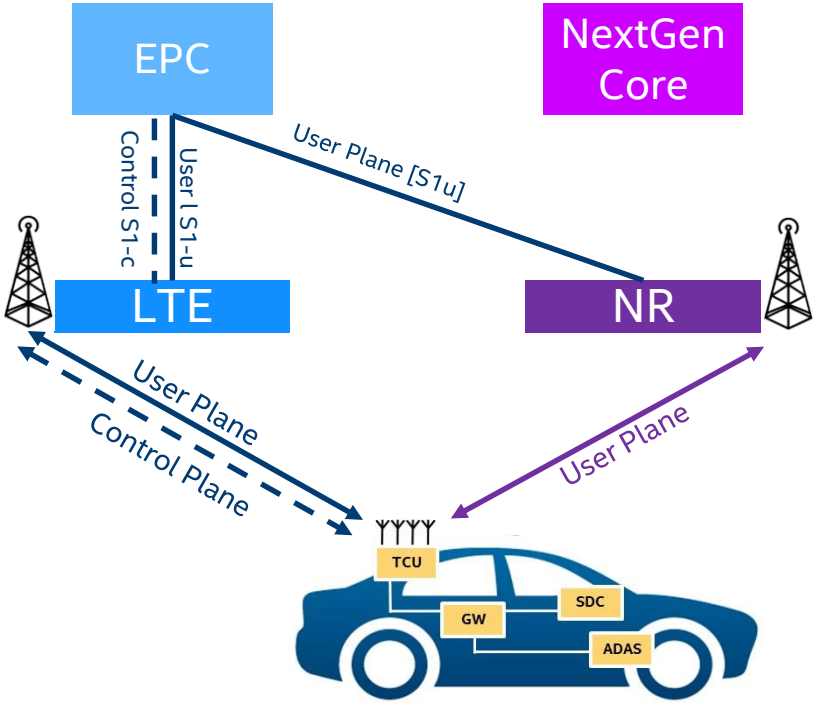
LTE and NR Carrier Aggregation Combinations Complexity Growth



- Continuing rapid increase in LTE CA combinations, currently **1577** specified*, with 35 LTE bands deployed, and upto DL-7CA combinations in standardisation
- NR CA combination (stand alone and dual connectivity) definition starting – already over **830** combinations*, and 39 NR bands defined
- Operators continue to define and deploy new combinations
- Adoption of downlink 4x4 MIMO, and uplink combinations leads to further complexity and CA permutations

* Including 3GPP Work Items

5G Architecture Option 3 [3GPP]
Non Stand Alone (NSA) - Dual Connectivity



Dual Connectivity Operation:
- LTE Control and User Plane
- NR User Plane

Two parallel Radio connections [Rx/Tx] required.

Impact on RF engine strongly dependant on the frequency bands used for simultaneous connections of LTE and NR and ability to utilise available resources (i.e. PAs)
(e.g LTE in Low Band, NR in UHB)
Options in discussion at 3GPP to minimise RF engine impacts on terminal side.

XMM™ 8162 Regional RF SKU Strategy

- Common RF FE architecture.
- Four Regional SKU proposed to cover key automotive markets
- Band support for each region shown, vs XMM™7662 LTE platform for reference

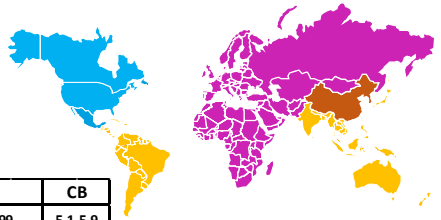


Illustration purposes - Overview of key region coverage
Not detailed country level analysis

Region	Conf	Low Bands 617-960MHz																Mid-Low 1428-1511			Mid Bands 1695-2200MHz										High Bands 2300-2690MHz						UHB 3.3-4.2 / 4.4-4.99					CB 5.1-5.9	
		71	26	5	6	18	19	8	12	17	20	13	14	28	a	b	29	11	21	32	1	25	2	3	3	66	4	34	39	7	30	40	41	41	38	42	48	n77	n78	n79	46	47
Global Superset		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	✱
SKU#1 North America	XMM8162	●		●				●	●	●	●	●	●				●				●	●	●	●	●	●				●	●		●				○					✱
	XMM7662	●		●				●	●	●	●	●	●				●				●	●	●	●	●	●				●	●		●									
SKU#2 EMEA	XMM8162			●				●	●		●			●	●					●	●		●	●		●			●				●			●			●			✱
	XMM7662			●				●	●		●			●	●					●	●		●	●		●			●				●									
SKU#3 China	XMM8162			●				●	●		●										●		●	●		●	●	●	●				●	●					●	●		✱
	XMM7662			●				●	●		●										●		●	●		●	●	●	●				●	●								
SKU#4 RoW incl Japan	XMM8162		●	●	●	●	●	●	●		●			●	●			●	●		●		●	●		●			●				●	●		●			●	●		✱
	XMM7662		●	●	●	●	●	●	●		●			●	●			●	●		●		●	●		●			●				●	●								

Legacy RAT (one of more of 2G,3G,4G)
C-V2x PC5
supported by chipset [auto use TBD]
Vehicle Tracking (option)

5G refarm band
5G/NR
Potential 5G/NR

Existing spectrum expected to be partially re-farmed to 5G/NR in timeframe of XMM™8162. current view based on 3GPP and operator insights.

DRAFT TARGET PROPOSAL
WORK IN PROGRESS
SUBJECT TO CHANGE

XMM7662: 2G/3G/4G
XMM8162: 2G/3G/4G/5G(NR)

XMM™ 8162 DL-CA Support

- The DL-CA target list is based on the requirements of ~20 Tier 1 worldwide operators, collected from Intel® close operator engagements, plus 5G/NR combinations defined in 3GPP - and results in over ~2000 DL-CA / MIMO combinations (including mmWave) for a worldwide LTE+5G/NR platform.
  - Operators:
    - North America: AT&T, VZW, TMO, Sprint
    - China: CMCC, CTC, CUC,
    - EMEA/RoW: VDF, TEF, Orange, EE, DTAG, Hutchinson, Optus, Telstra, Swisscom
    - Korea: KT, LGU+, SKT
    - Japan: DoCoMo, KDDI, SBM

XMM™8162 RF Front End Architecture
Managing the complexity

- **Sub6**
  - Highly integrated, single RF transceiver for 2G/3G/4G/5G – SMARTi™9
  - Scalable RF Front End Engine architecture based on RF modules (“PAMiD” aka “SPAD”) which integrate: PA, Duplexers, Filters, switches etc for each band group - Low Bands / Mid-High Bands / Ultra High Bands

- **mmWave**
  - VirginaPeak mmW front end module with patch antennas
  - SMARTi9m to convert RF to digital interface

SMARTi™ 9 RF Transceiver Overview
Supporting 2G, 3G, 3G, TDSCDMA, CDMA, 4G, 5G(NR)

Receiver
- Frequency support from 600MHz to 6GHz
- 28 Receive ports
- 4x4 MIMO support for LTE/NR
- 6 RX LO support supporting up to 6 bands/sub-blocks

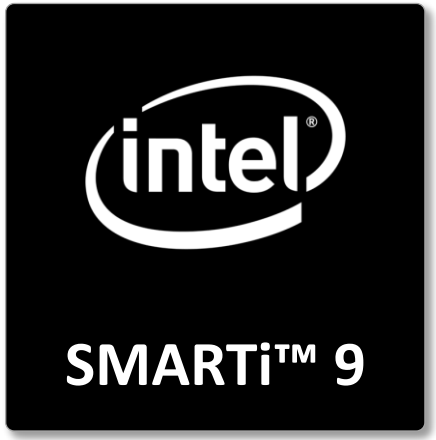
Digital Transmitter
- 2 transmitters for DB-ULCA LTE or DC-LTE/5G NR
- UL 2x2 MIMO support for 5G NR
- UL BW of up to 200MHz (contiguous) for 5G NR

GNSS
- 6-mode dual receive GNSS (L1, L5/L2)

RF/BB-Interface
- SMARTiConnect - High speed digital interface

Reference Clock
- 76.8 MHz reference clock frequency

Miscellaneous
- Reduced amount of external components/discretes



Future Flexibility & Scalability

potential TRX Configurations within XMM™ 8162

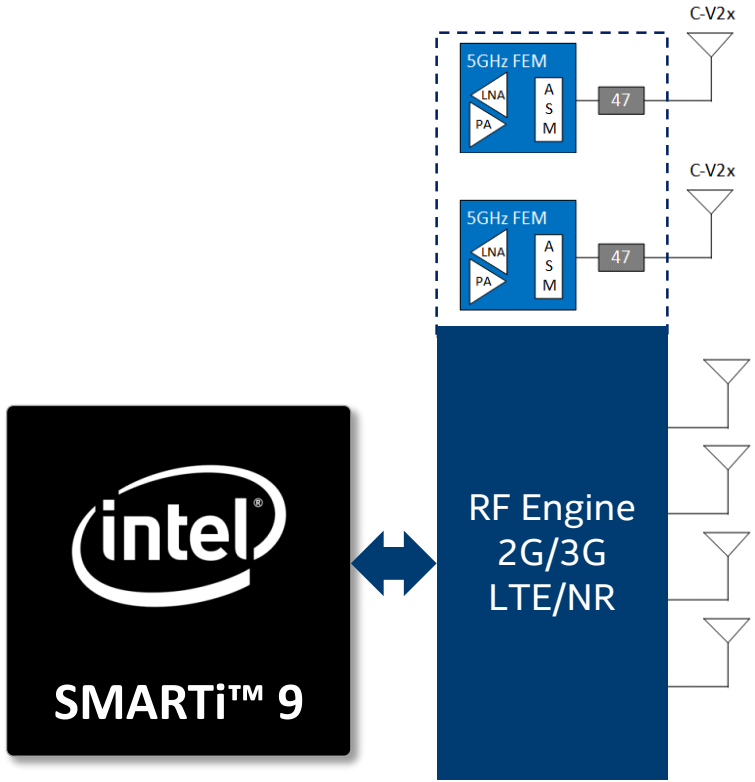
		1x SMARTi 9	2x SMARTi 9	3x SMARTi 9	Comment
Single SIM	NR-SA	Yes			
	NR-SA + PC5	Yes			Most Cost sensitive offering if PC5 mandated
	NR-NSA	Yes			
	NR-NSA + PC5		Yes		
Dual SIM	NR-NSA + NR-SA		Yes		
	NR-NSA + NR-NSA		Yes		
	NR-NSA + NR-SA + PC5		Yes		Maximum of NR-SA or LTE on Modem with PC5 support.
	NR-NSA + NR-NSA + PC5			Yes	Super set solution with maximium future flexibility, dedicating one S9 to PC5 sidelink

Priority configuration needs to be aligned with Customer
mmWave configuration are not shown on this table, but can only exist with 1 or 2 SMARTi 9 configurations

SMARTi™ 9 and C-V2x [PC5] support in B47

Receiver
- 28 Rx ports
  - 4 ports supporting upto 5.925 GHz for either:
    - n79 with 4x4 MIMO
    - or C-V2x [PC5]

Digital Transmitter
- 3 transmit blocks with multiple output ports:
  - TX1 – upto 4.2GHz
    - 3G / LTE / NR bands upto n77
  - TX2 – upto 5.925GHz, for:
    - 3G / LTE / NR bands upto n79
    - ULCA or EN-DC together with TX1
    - or C-V2x[PC5]
  - TX2m – upto 5.925GHz for:
    - UL 2x2 MIMO [MB, UHB, n79] with TX2 [same freq]
    - or C-V2x[PC5] Tx Diversity



1x SMARTi9 can support either:	**LTE [UL-2CA 2B] , 5G [NSA mode]**	**w/ UL 2x2 MIMO**	**without C-V2x[PC5]**
or	**LTE [UL-2CA 1B] , 5G [SA mode]**	**w/o UL 2x2 MIMO**	**with C-V2x[PC5]**

SMARTi™ 9 and C-V2x [PC5] support in B47

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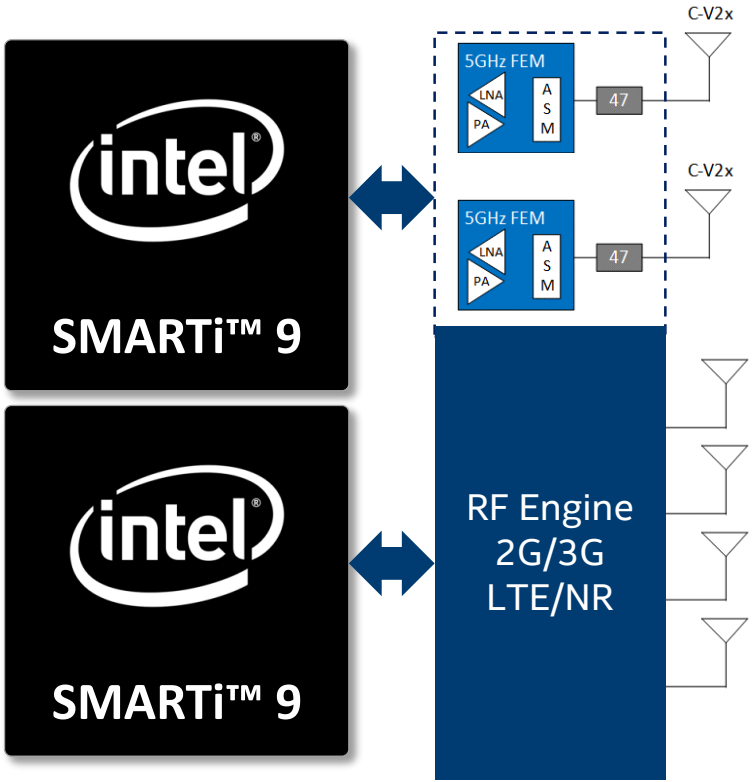
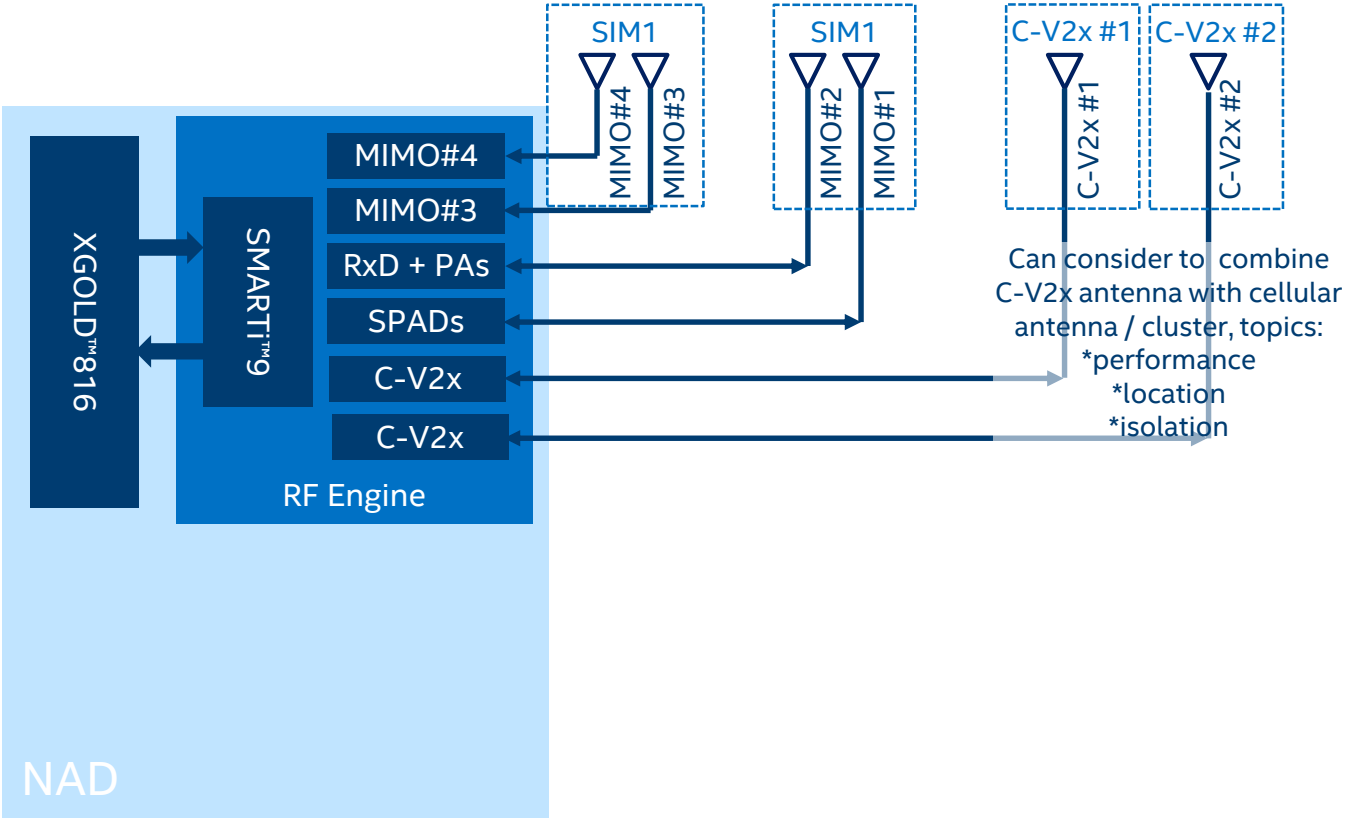


2x SMARTi9 can support: **LTE [UL-2CA 2B] , 5G [NSA mode] w/ UL 2x2 MIMO with C-V2x[PC5]**

XMM™8162 RF Engine and antenna configuration



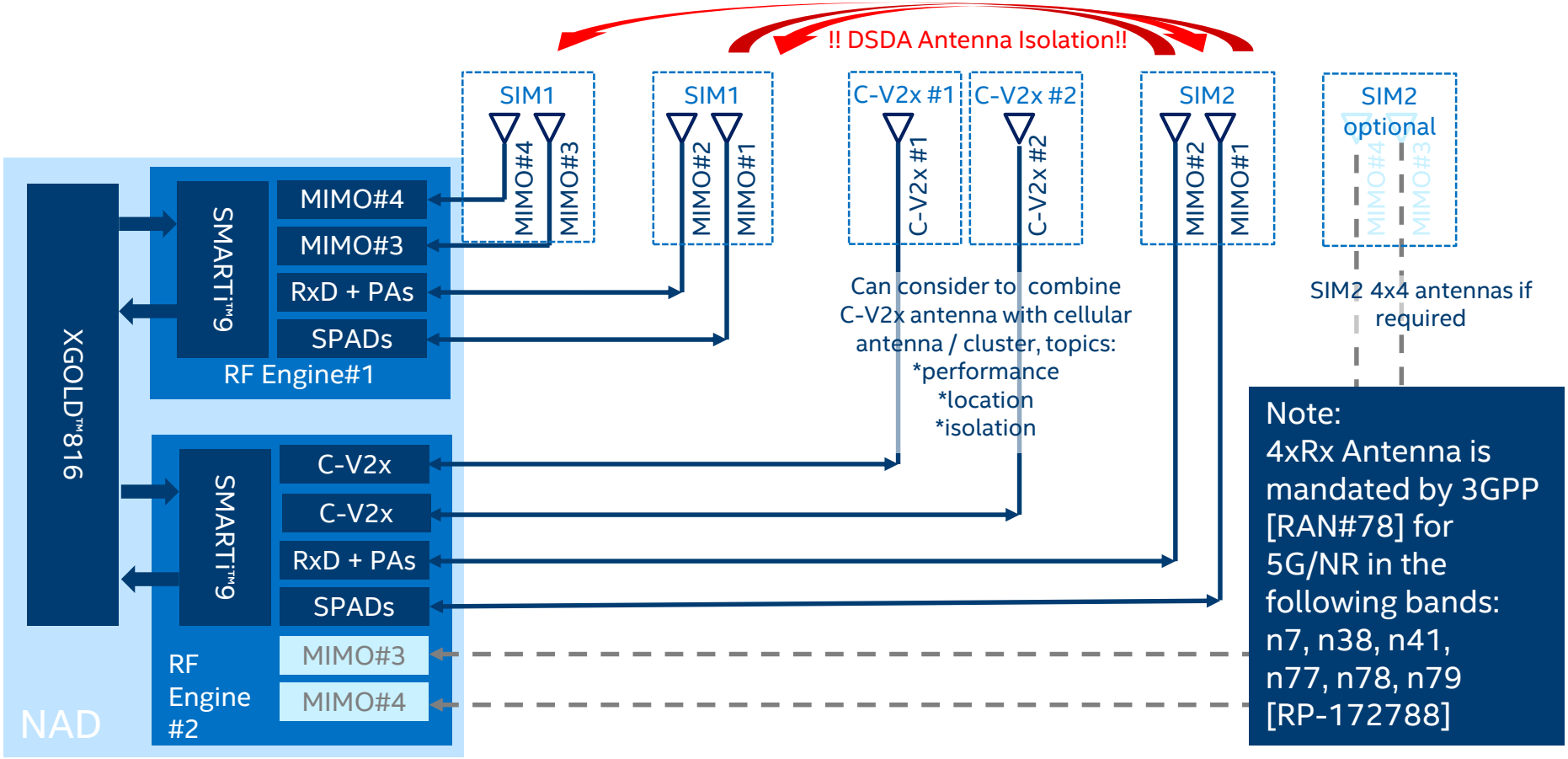
Note:
4xRx Antenna is mandated by 3GPP [RAN#78] for 5G/NR in the following bands: n7, n38, n41, n77, n78, n79 [RP-172788]

Antenna Sharing options for Cellular-V2x PC5

V2x antennas shared with:	Advantages	Disadvantages
Cellular Main and Diversity antennas	Expected to be closest to TCU Lower coax losses Omnidirectional antenna Same solution for 2 antenna variant	Very wideband antennas required ~600MHz-5.9GHz Insertion loss of multiplexer impacts RF performance in all bands
Cellular MIMO3/4 antennas	Simpler antenna design: Narrower bandwidth:1710-5.9GHz Simpler antenna triplexer, no additional loss for legacy Tx	Not all variants may have 4x4 MIMO Antenna location issue for C-V2x?
Re-use DSRC antennas	Either/or mounting option to use 5.9GHz DSRC antennas for C-V2x when DSRC is not fitted	DSRC/C-V2x is an either /or
External WiFi antennas	Share existing 5.8GHz antenna Potential sharing of HW resources between WiFi and C-V2x optimising cost Simple antenna diplexer 2.4/5.8GHz	Antenna location issue for C-V2x? Access to WiFi subsystem if not in TCU Arbitration scheme for sharing. Co-existence to WiFi

XMM™8162 DSDA RF Engine and antenna configuration

Last updated: 23 Jan 2018



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  - GNSS Subsystem
  - RF Front End
  - KPIs
- Reference & Evaluation Platforms

KPIs

Temperature Target for XMM™ 8162

Temperature Targets for XMM™ 8162 chipkit	Tjunction (Silicon Die)		Crystal (1mm PCB)	
	Min	Max	Min	Max
3GPP Compliance for Intel Silicon	-40C	+100C	-40	+95C
Normal Operation & Lifetime Reliability	+100C	+110C	‘+95C	+105C
Restricted Operation (no Lifetime Reliability for Silicon) - No Guaranteed Function, No Silicon Reliability	+110C	+125C - Tolerance	+105C	+120C - Tolerance

Note: Tolerance Target for High Temperature operation is 2.5C

Typical Low Activity Use Cases

x = Key paramter to influence power consumption for relevant use case

	Use case	Summary	Technology Node & chip design	DRX cycle	Neighbors Cells	Bandwidth	Connected-DRX	FDD or TDD	Carrier Aggregation	Tr. Time Interval (TTI)	Power Consumption Range 25C (mW) Min	Power Consumption Range 25C (mW) Max
	Off Mode	System is powered down, requiring ~10secs for an IP connection to Network.	x								<0.5	
	No Radio	Airplane mode: modem enters and stays in Deep Sleep	x								~2.9	
Incoming Paging possible	Idle-DRX Static	Static DRX Idle scenarios with strong signal where neighbor searches are not required per 3GPP		x		x					5.5	7.5
Incoming Paging possible	Idle-DRX w/ simulated live network conditions	Extension of the DRX Idle Static but with fixed (unvarying) signal conditions so that neighbor searches are required per 3GPP and there are 1 or more measureable: Intra, Inter & iRAT neighbors so that the mobile will perform both neighbor search and measurement as well as neighbor reporting		x	x	x					7.0	10
Data Connection No transfer	Connected-DRX (C-DRX)	Connected but only required to monitor the PDCCH every DRX cycle for a specified on Duration but with no RB allocations received				x	x	x	x		20	30
Data Connection No transfer	LTE PDCCH no data	Mobile is in a connected state and monitoring the PDCCH every TTI but with no RB allocations received				x		x	x	x	200	->

1. Transition from LTE PDCCH (No Data) to Connected-DRX is controlled by Network and typically happens in **< 1sec**. Transition from C-DRX to Idle-DRX happens after **~10secs** Note1
2. An always on Car Conection, would require short Periodic TAU, on regular basis (typically 1-2hours). Power consumption is a function of distance from Call tower & frequency of Periodic TAU.

Note1: Based on small sample measurements on European Operator, if no data transfer.
Note2: Refers to Modem subsystem, incl PAs and LNA, excludes AP system, Ethernet or other I/O connections ; **Note3**: Power Values may change to meet Automotive Quality & Lifetime Reliability Requierments

TCU Power States – Intel Assumptions

power states / Components	Normal Operating Mode	Low Power Mode	NAD Always-On Mode	Sleep Mode
XMM™ Modem	Registered to network, end-to-end IP connection established to AP	Registered to network, end-to-end IP connection established to AP	Registered to network, either CS-attached only, or “keep-alive” mode with IP connection established (Intel proposal: LwIP on Modem).	Powered off
AP CPU	Resumed state, in power-saving mode (S0idle)	Resumed state, in power-saving mode (S0idle)	Resumed state, in power-saving mode (S0idle) or Sleep state (suspend-to-RAM), needs to be active regularly for keep alive message generation	Powered off
Vehicle Bus (Ethernet)	Powered on	Powered off	Powered off	Powered off
Wake-up capabilities	Airbag line, eCall button line	Ethernet wake-up line or CPU request based on incoming telematics message, Airbag line, eCall button line	Wake-up by SMS, incoming wake-up voice call or “magic” IP packet (“keep-alive” mode only), Airbag line, eCall button line, Ethernet wake-up line	Only external wake-up possible, Airbag line, eCall button line, Ethernet wake-up line
NAD Power Estimate	See power KPI slide	See power KPI silde	8.7 mW (0dBm PA output)	<0.5 mW

XMM8162 Boot KPIs for Automotive

	Flashless	Flash-based
Mini-AP boot to Ethernet IPC & Linux ready	n/a	6s
C-V2X PC5 (Mode4) / GNSS Sync boot to transmission of 1st BSM (assumption: valid extended ephemeris for GNSS sync)	3s	6s
Boot to LTE NW attach	6s	9s
Boot to eCall start	7s	10s

Note 1: In the flashless configurations the boot time of the external TCU AP needs to be considered. 3s before modem flashing/boo starts seem to be a fair assumption.

Note 2: Loading the modem FW image through PCIe happens with 2-3 times higher throughput that loading the inmage through a NAND interface.

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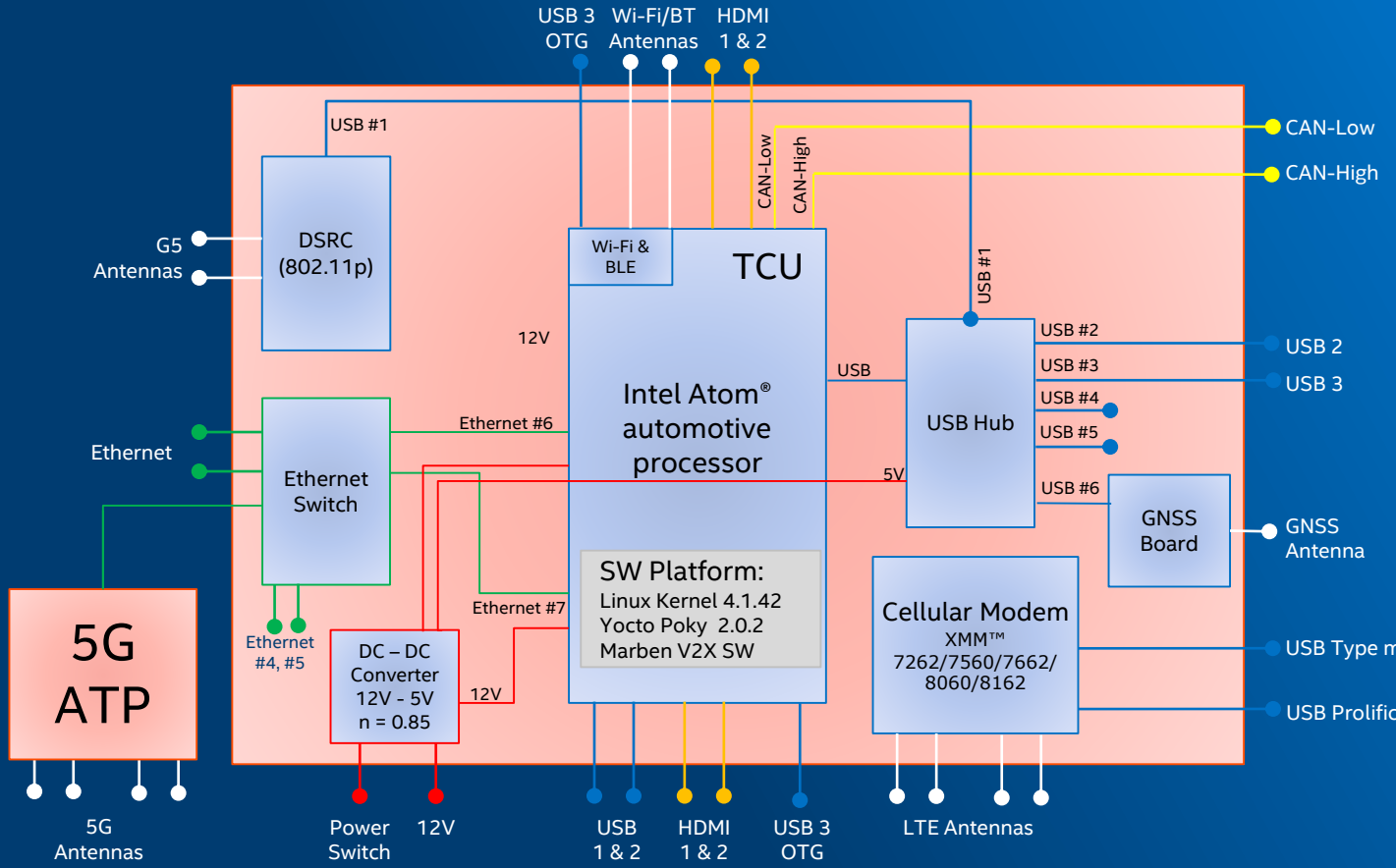
TCU / CV2X Reference Platform

TCU/C-V2X REFERENCE PLATFORM

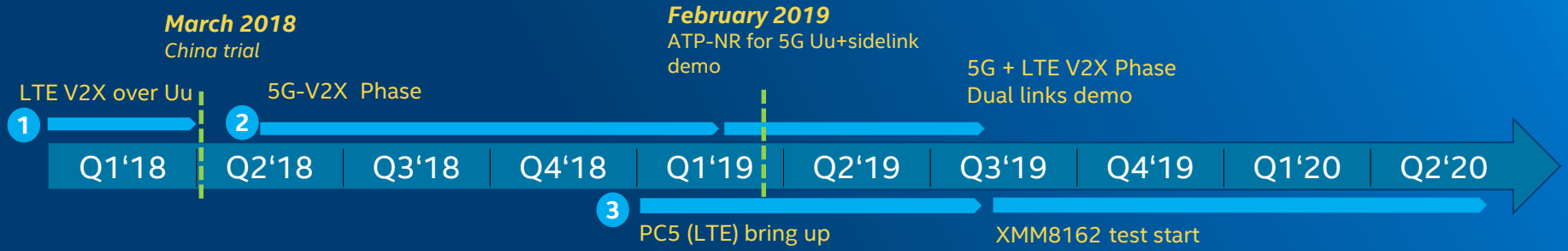


V2X REFERENCE PLATFORM TIMELINE

1. Uu-only-Phase (Q1‘18): LTE V2X over Uu - ongoing
   - optional - eMBMS trial with NV partner

2. **5G-V2X-Phase: 5G V2X with ATP**

3. **PC5-Phase: LTE V2X over PC5**
   - Demonstrate LTE V2X PC5



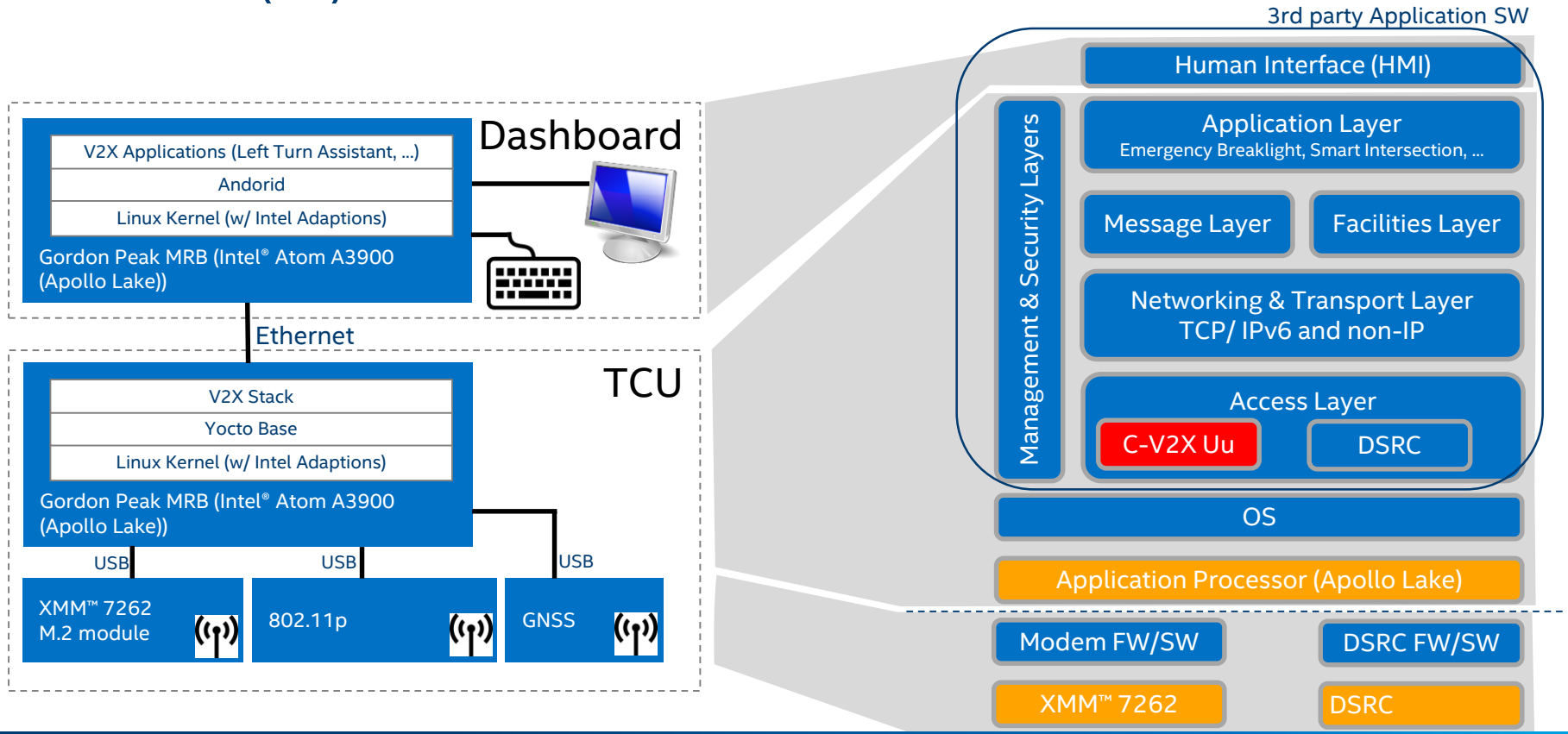
TCU/C-V2X Reference Platform status

- Reference Platform HW in place and functional at 3 R&D locations
- 3rd Party V2X Application stack available and running on Intel HW
- UI for demo Phase 1 (C-V2X Uu) available
- Live testing in Shanghai International Automotive City March 26-29, 2018

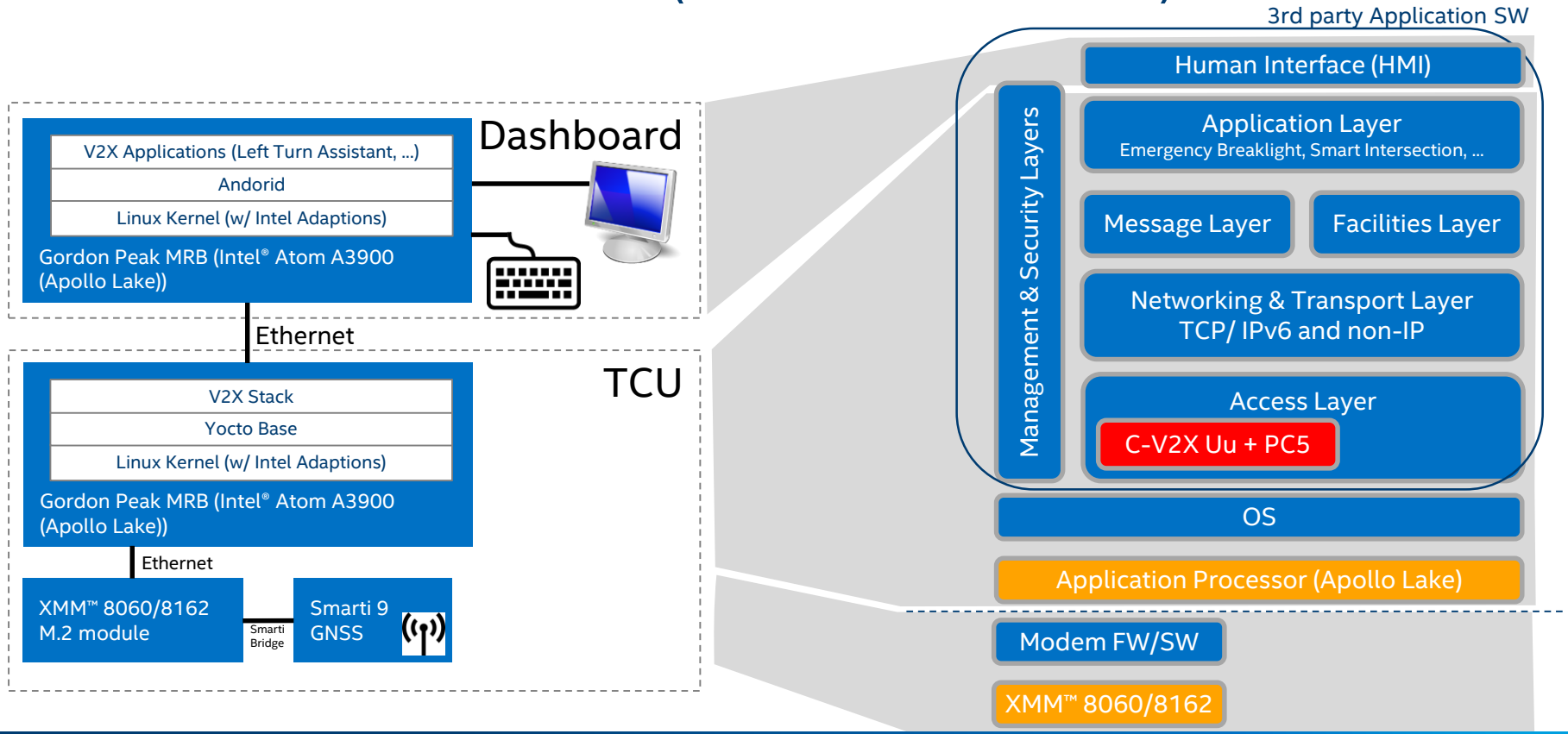
Shanghai International Automotive V2X testcases

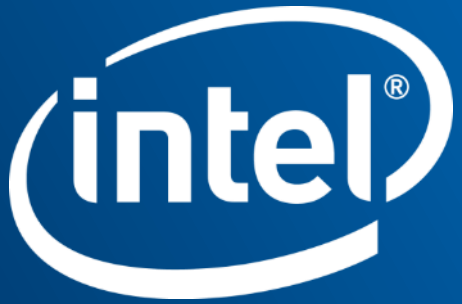
V2X test cases	V2X	Comments
Red light warning	V2I	
Green light Guidance	V2I	Remaining green light, speed compliance
See through	V2I	Car A is in front of B, B is able to see A's front camera
Emergency Breaking Warning	V2V	
Overtake Warning	V2V	
Collision Avoidance Warning at Cross	V2V	
Platooning	V2V	
Pedestrian Collision Avoidance Warning	V2P	

HW and SW Setup of LTE V2X (Uu) Reference Platform



HW and SW Setup
of LTE V2X Reference Platform (3GPP Rel.15 PC5 & Uu)





Intel Communication and Devices Group