Connected Car: Platform for Innovation

Nakul Duggal
Vice President, Product Management, Automotive
Qualcomm Technologies, Inc.
All major automakers use Qualcomm Technologies

Acura • Audi • BMW • Buick • BYD • Cadillac
Chevrolet • Chrysler • Dodge • Ford • Geely • Honda
Hyundai • Infiniti • Jaguar • Jeep • Kia • Land Rover
Lexus • Lincoln • Mercedes • Mini • Nissan • Opel
Porsche • PSA • Renault • Rolls-Royce • Smart
Subaru • Toyota • Tesla • Volvo • VW

Source: Company data

* Infotainment and telematics designs
Powering the next-generation car with today’s broad portfolio of automotive solutions

**Connected & Cockpit Gateways**
- Cloud-connected
- Emergency-calling
- Over the air updates
- WiFi/BT hands free
- Global positioning
- WiFi Hotspot
- Vehicle-to-X
- Passive Keyless Entry
- Real-time navigation
- Multimedia / BYOD
- Electronic horizon
- Instrument Clusters
- Rear-seat entertainment
- Domain controllers
- SW & OS integration
- App virtualization

**Autonomy & Safety**
- Emergency Braking
- Fwd Collision Warning
- Auto-park assist
- Blind spot detection
- Pedestrian detection
- Moving object detection
- Surround View
- Forward facing camera
- Median Lane
- Lane Change assistance
- Cruise control
- Adaptive Cruise control
- Car-As-A-Service
- Robotaxi

**Multi-Os Support**
- DSP
- Wi-Fi / DSRC
- Bluetooth
- Multi-OS support

**Multimedia & Power Management**
- GPU
- RF
- Software/HLOS
- Position Location
- Powerline
- Ethernet
- Security

**EV Charging**
- PLC
- 3G/4G LTE
- 5G/C-V2X
- 5G/C-V2X

**CO2-Free**
- Full & Hybrid Electric Vehicles
- Charging Station infrastructure
- Vehicle charging outlet
- EV battery management systems

**Computer Vision**
- Computer Vision
Connectivity is a key pillar for automotive innovation

Penetration per 100 new vehicles estimated in 2025

Cellular-connected vehicles (incl. 5G)  Autonomous vehicles (SAE L4/5)

Source: Strategy Analytics, Oct.-Nov. ‘17; Cellular-connected data extrapolated from analyst forecast until 2024. Standard (mid scenario) forecast for autonomous vehicles.
Over 15 years of wireless connectivity in automotive as cars move toward 100% connectivity

### 2003
- **2G, 3G, GNSS (10m)**

#### SOFTWARE
- **Linux**

#### MODEM
- **GSM, 1x, EV-DO, UMTS**
- **DC-HSPA, TD-SCDMA, LTE, 4x4 MIMO, ULL-C6, LTE-A, 5G, DSDA (Car + Owner SIM)**

#### POSITIONING
- **GPS, Galileo**
- **GLONASS, Beidou, MF-GNSS, Dead Reckoning**

#### CPU
- **ARMv7**

#### POWER MANAGEMENT
- **Linux**, **QNX, Virtualization**

### 2018+

#### SOFTWARE
- **Linux**

#### MODEM
- **GSM (1+ per car)**
- **1x, EV-DO, UMTS**
- **DC-HSPA, TD-SCDMA, LTE, 4x4 MIMO, ULL-C6, LTE-A, 5G, DSDA (Car + Owner SIM)**

#### POSITIONING
- **GPS, Galileo**
- **GLONASS, Beidou, MF-GNSS, Dead Reckoning**

#### CPU
- **ARMv8 high performance**

#### POWER MANAGEMENT
- **SECURITY**
- **TrustZone, DRM**

### FEATURES
- **CONCIERGE SERVICES**
- **ROADSIDE ASSISTANCE**
- **EMERGENCY CRASH NOTIFICATION**
- **REMOTE DIAGNOSTICS & MANAGEMENT**
- **STOLEN VEHICLE RECOVERY**
- **WI-FI HOTSPOT FOR HIGH-SPEED ACCESS**
- **HD NAVIGATION W/ CROWDSOURCING**
- **OVER-THE-AIR SOFTWARE UPDATES**
- **CONTENT STREAMING**
- **TELE-OPERATIONS**
- **DUAL-SIM-DUAL-ACCESS (CAR SIM + OWNER SIM)**
- **MULTI-OPERATOR CONNECTIVITY & SUBSCRIPTION MANAGEMENT**
- **EDGE-PROCESSING & DATA ANALYTICS**

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**RF TRANSCEIVER**
- **2G / 3G / 4G / 5G GNSS**

**LOW NOISE AMPLIFIER**
- **TrustZone, DRM**

**ENVELOPE TRACKER**
- **Switch, Duplexer Switches, Filters**

**CONNECTIVITY**
- **802.11ac / ax**
- **802.11ad**
- **Bluetooth / BLE**
Evolution of the connected car

<table>
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<tr>
<th>2003</th>
<th>2018+</th>
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<td>5G NR based C-V2X</td>
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<td>C-V2X</td>
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<td>Multi-Hz GNSS Reckoning (DR)</td>
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<td>VIO*</td>
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<td>Linux enabled</td>
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<tr>
<td>802.11ac</td>
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<td>802.11ad</td>
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<td>Bluetooth</td>
<td>CAN</td>
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<td>Powerline</td>
<td>Ethernet</td>
</tr>
<tr>
<td>EV charging PLC</td>
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</tbody>
</table>

* Visual inertial odometry
Connectivity in a Car

Enjoy your personal content, manage your car and safety communication through V2V & V2I

Identity
- Single SIM
- Dual SIM (DSDA)
- V2X certificates

WWAN connectivity
- Switch operators with cloud-based switching
- eSIM contains multiple operator identities
- Better coverage, flexible commercial arrangement
- Multiple frequency bands / operators

Business models
- OEM can preload minutes of connectivity for usage

V2X device configuration
- V2V, V2I, high precision GNSS
C-V2X
Establishes the foundation for safety use cases and a continued 5G NR C-V2X evolution for future autonomous vehicles

- V2V: Vehicle-to-vehicle e.g., collision avoidance safety systems
- V2I: Vehicle-to-infrastructure e.g., traffic signal timing/priority
- V2P: Vehicle-to-pedestrian e.g., safety alerts to pedestrians, bicyclists
- V2N: Vehicle-to-network e.g., real-time traffic/routing, cloud services

Enhanced range and reliability for direct communication without network assistance

- Release 14 C-V2X completed in 2017
- Broad industry support—5GAA
- Global trials started in 2017
- Our 1st announced C-V2X product in September, 2017
C-V2X offers key advantages in multiple dimensions

- Enhanced range and reliability
- Up to 500km/h relative speed support
- More cost efficient than other technologies
- Forward compatible evolution path to 5G

Enhanced range and reliability for direct communication without network assistance

Self managed for reduced cost and complexity
Synergistic with cellular modem
Leverage of cellular ecosystem
Reuse of SAE/ETSI upper layers

NR
### V2X communications - V2V, V2I, V2N ➔ Direct (PC5) and Network (Uu)

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<td>Local, Real-time</td>
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C-V2X now at the confluence of automotive and wireless innovation

5GAA is a cross-industry consortia to help define C-V2X and its evolution to 5G

Automotive industry
Vehicle platform, hardware, and software solutions

Telecommunications
Connectivity and networking systems, devices, and technologies

End-to-end solutions for intelligent transportation mobility systems and smart cities

Source: http://5gaa.org/; accurate as of January, 2018
Connectivity is a key driver for car innovation

- Cellular to be available in more than 75% new vehicles by 2025 vs. 1% autonomous cars
- Spanning across key automotive domains: Telematics, infotainment, safety / autonomy
- Wireless innovations such as Gigabit LTE, C-V2X and 5G will feature new use cases and business models
- Mobile ecosystem is well-positioned to support the technologies required by increasingly connected, smart, autonomous vehicles
Thank you!

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