Delivering Innovation in CBTC and Energy Management

APTA Rail Conference

June 12th, 2018
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2. Our Wireless System Developed with Huawei
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Introduction to the BYD SkyRail

SkyRail is a Straddle-type, medium-high capacity, driverless, urban monorail system that runs on elevated 700 mm (27.5 inch) beams that both support and guide the trains.

SkyRail is a viable elevated line-haul alternative wherever low cost at-grade alignments are not available.

Incorporates all of the evolutionary improvements from the past 60 years seen in other forms of rail transit.
SkyRail Development

- Numerous projects awarded, multiple under construction simultaneously
- All under a turn key, fully integrated approach
SkyRail’s Wireless System

• BYD co-developed with Huawei SkyRail’s wireless communication system.
  • Called LTE-U, it integrates both the signaling and communication system
  • Uses LTE, not WiFi, at 5.8 GHz in unlicensed spectrum
  • Primarily responsible for transmission of: CBTC, PIS, CCTV, Onboard WiFi

• LTE-U follows the standard set forth by the MulteFire Alliance
The MulteFire Alliance

- Dec 2015, MulteFire Alliance founded
- Jun 2016, Huawei joined MulteFire
- Jan 2017, MulteFire specification v1.0 released
- Voice over LTE-U will be supported by handset chipset in 2018
## Key Benefits

<table>
<thead>
<tr>
<th></th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LTE</strong></td>
<td>• Wide coverage</td>
<td>• Spectrum license needed</td>
</tr>
<tr>
<td></td>
<td>• Seamless mobility</td>
<td>• Large and complex network</td>
</tr>
<tr>
<td></td>
<td>• Numerous connections</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Carrier-grade robustness</td>
<td></td>
</tr>
<tr>
<td><strong>Wi-Fi</strong></td>
<td>• Free spectrum</td>
<td>• Short coverage</td>
</tr>
<tr>
<td></td>
<td>• Easy to deploy</td>
<td>• Weak mobility</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Limited connections</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Vulnerable to interference</td>
</tr>
</tbody>
</table>

**eLTE-U**
- Unlicensed 5 GHz
- LTE-like performance
- Wi-Fi-like deployment
- 3GPP based, future-proof
A General Comparison

On-board (EPC)

AirNode

OCC

Wayside

Double layer cover

On-board

TAU

LTE-U comprehensive carrying system

General carrying net

CBTC

PIS

PA

CCTV

A net

B net

Trunked dispatch

CBTC

PIS/CCTV

WiFi

senser

General carrying net
Strong Anti-interference Capability

- Incorporates Orthogonal Frequency Division Multiplexing (OFDM) modulation
- Stronger multi-path signal processing capabilities than Wi-Fi
  - LTE-U: Combine and enhance multiple-reflection wireless signals
  - Wi-Fi: Choose the strongest one, abandon the others as interference

OFDM modulates to find the best portion of spectrum when interference is present

Dense Cities:
- LTE-U throughput drop: 20%
- Traditional unlicensed technologies: 50 to 70%

Strong Interference:
- LTE-U throughput drop: 30%
- Traditional unlicensed technologies: unable to establish a connection
E2E Encryption Ensures Network Security

1. Air-interface Encryption
   - Dual authentication between device and Base station

2. IPSec
   - IPSec ensures security between Base station and network server

- Video Application Platform
- Base Station
- Device

- Encryption
- IPSec

Equipment
- Data
- Signaling
- O&M

Transmission isolation design by port, VLAN, IP subnet, and IPSec

Route table isolation architecture design

Prevent any penetration
Additional Benefits

- **Advanced Base Station Power Boosting**
  - Wi-Fi
  - eLTE-U
  - Two to three times larger coverage
  - 10 dB difference

- **Base Station Spacing**
  - LTE-U: 700 m, WiFi: 200 m
  - Capable of 100 mph handovers without package loss

- **Train positioning**
  - Communicated 5 x per second
  - 200 ms

- **Cell throughput**
  - Concurrent users
  - Traditional unlicensed technology
  - eLTE-U can process concurrent services from 128 terminals with no significant deterioration in throughput.
### eLTE-U Network Elements and Specifications

#### Core Network
Server managing AirNode, with standard interface to enterprise’s management and application system.

<table>
<thead>
<tr>
<th>eCore (3U)</th>
<th>eCore (1U)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200,000 users</td>
<td>10,000 users</td>
</tr>
<tr>
<td>3,000 base stations</td>
<td>100 base stations</td>
</tr>
<tr>
<td>24 Gbit/s</td>
<td>2.5 Gbit/s</td>
</tr>
<tr>
<td>130.5 mm x 442 mm x 675 mm</td>
<td>43.6 mm x 442 mm x 310 mm</td>
</tr>
</tbody>
</table>

#### AirNode
The AirNode is in charge of radio transmission and receiving. The highly integrated AirNode simplifies the site acquisition and network deployment.

- **Frequency Bands**: 5.470 GHz to 5.725 GHz; 5.725 GHz to 5.850 GHz
- **External Ports**
  - One Ethernet port (RJ45)
  - One USB port
  - One SIM card slot
- **Cell Bandwidth**: 20 MHz
- **Number of TX and RX Channels Per Cell**: 2T2R
- **Maximum TOC Power of Each Channel**
  - 5.8GHz: ≤ 21 dBm (125 mW)
  - 5.4GHz: ≤ 16 dBm (40 mW)
- **Dimensions**: 290 mm x 210 mm x 60 mm
- **Input Power**: PoE power supply: -48V DC
- **Transmission Port**: One FE/GE electrical port

#### Terminal
**DAU eA680**

<table>
<thead>
<tr>
<th>Frequency Bands</th>
<th>LTE TDD 5G: 5.470 GHz to 5.850 GHz; WLAN: 2.400 GHz to 2.4835 GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum EIRP</td>
<td>5.8GHz: 36dBm, 5.4GHz: 30dBm</td>
</tr>
<tr>
<td>Dimensions</td>
<td>205 mm x 205 mm x 85 mm</td>
</tr>
<tr>
<td>Weight</td>
<td>About 3 kg (excluding power adapters)</td>
</tr>
<tr>
<td>Protection Class</td>
<td>IP67</td>
</tr>
<tr>
<td>PoE</td>
<td>Supported</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>-40°C to +65°C</td>
</tr>
</tbody>
</table>

- **Mini-PCIe**
  - Size: 50.95 mm x 30 mm x 4.75 mm
  - Weight: < 20g
  - Port: Serial/USB Port
  - Power: DC 3.3V
Real Time Data, All in One Place
Our Cloud Network

- IoT Cloud platform with centralized hardware which is scalable, allowing load balancing and is integrated with a plethora of software services
- AI, IoT Sensors and Machine Learning assists with improvements in all aspects of the project

**Data Management**

- Vehicle Database
- Signal Database
- Operations Database
- Construction Database

**Vehicle**
- Doors
- Bogies
- Traction Power & Braking
- Coupling
- Grid Power Supply
- Control & Diagnosis
- PIS & Monitoring

**Signaling**
- Train Monitoring & Tracking
- Train Dispatch
- Routing
- Device Data

**Communications**
- ICSC
- Monitoring System
- Transfer System
- Security Controls
- PA
- AFC
- PIS

**Construction**
- Guidebeam
- Depot
- Machine Shop
- UI
- Electrical System Design
- Base Data

**Operations**
- EAM
- Maintenance
- OA

**Ridership**
- Travel Habits
- Interest
- Payment Habits

**Our Cloud Network**

- • IoT Cloud platform with centralized hardware which is scalable, allowing load balancing and is integrated with a plethora of software services
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Energy Management

Energy Regeneration & Wayside Battery Energy Storage

On-Board Batteries
After 9,500 cycles, the battery capacity still remains at 70.7%. The degradation curve is also much more stable than other chemistries.

➢ Whole vehicle packs (with multiple modules) have been tested under continuous load, raising the surface temperature of the modules to 40 °C. However, even under these harsh conditions, the capacity has remained at over 85% after 2,000 cycles, and over 75% after 4,000 cycles.

Test method: 1C/1C@25°C, 100%DOD
2.6 Efficient Charge-Discharge Performance

C-rate Charge Curve

C-rate Discharge Curve

Charge at Temp. Curve

Discharge at Temp. Curve
Onboard Backup Batteries

- Onboard batteries serve two purposes:
  - Provide backup traction power in event of regional power outage
  - Eliminates need for power rail in maintenance facilities

- 16 kWh capacity, 3.1 mi range
Energy Regeneration & Wayside ESS

- Wayside ESS Serves two purposes:
  - Reduction in system energy consumption
  - Net voltage stabilization
- Typical installation is 1 MWh of capacity
- Spacing is approximately 2 miles apart
  - Depends ultimately on alignment conditions

Recharge under braking
Discharge under acceleration
Reduced Energy Consumption
General Layout
Net Voltage Regulation

Power Rail Voltage & Time

With ESS
Without ESS

Deceleration
Acceleration
Deceleration
Thank you!