Delivering Innovation in CBTC and Energy Management

APTA Rail Conference

June 12th, 2018

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byd.com/usa/skyrail

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BYD Business Divisions

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Consumer Vehicles

SkyRail

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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

Yinchuan, China

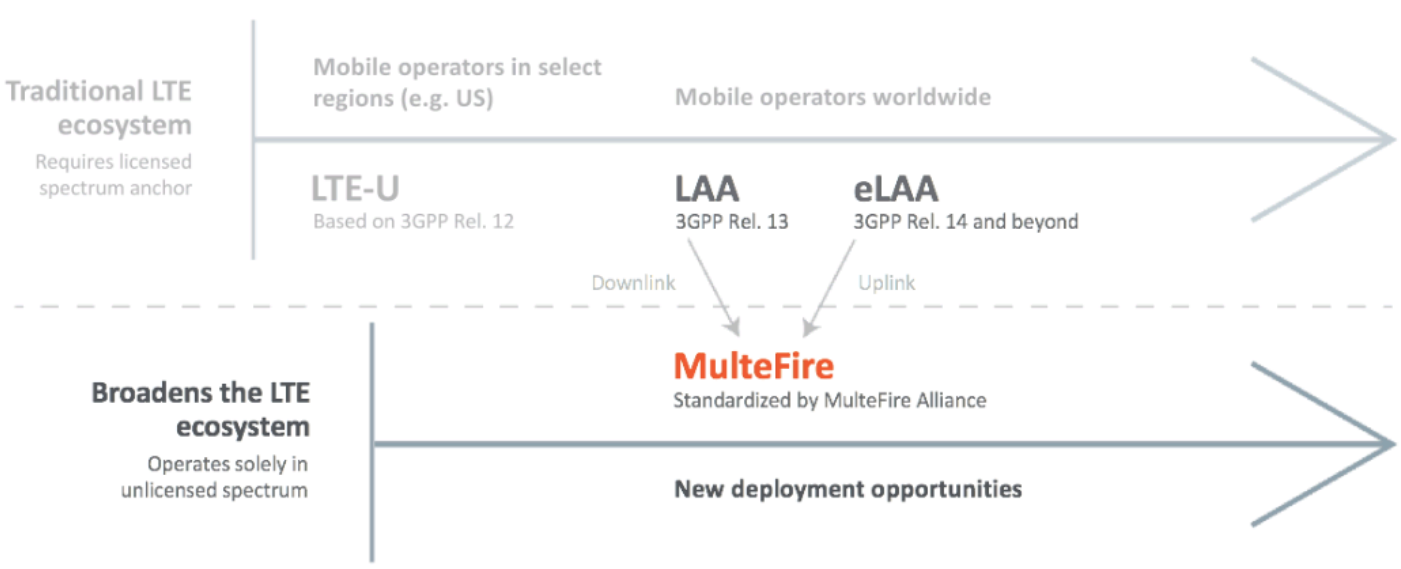
Shenzhen, China

- 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

MulteFire Alliance Member

Chipset

QUALCOMM intel

Test vender

ROHDE&SCHWARZ SANJOLE

Network

HUAWEI ERICSSON NOKIA CISCO

SpiderCloud Wireless Ruckus BaiCells exfenet SERCOMM

Service provider

SoftBank ATHONET boingo

LIBERTY GLOBAL Charter COMMUNICATIONS casa systems COMCAST

Key Benefits

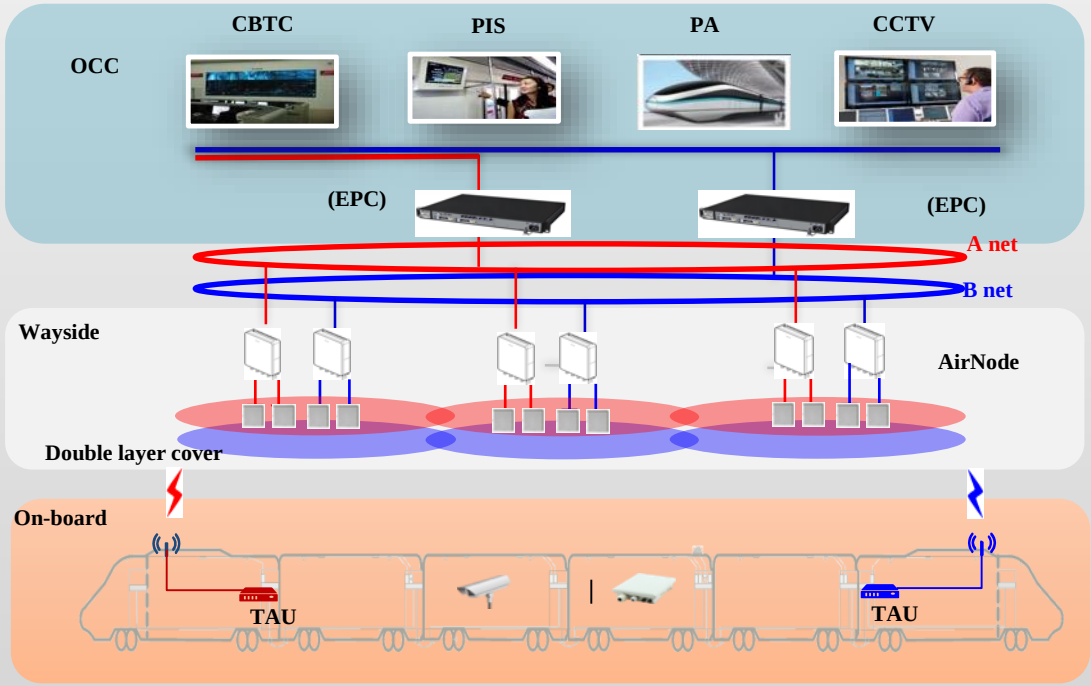
	Pros	Cons
LTE	• Wide coverage • Seamless mobility • Numerous connections • Carrier-grade robustness	• Spectrum license needed • Large and complex network
Wi-Fi	• Free spectrum • Easy to deploy	• Short coverage • Weak mobility • Limited connections • Vulnerable to interference

eLTE-U

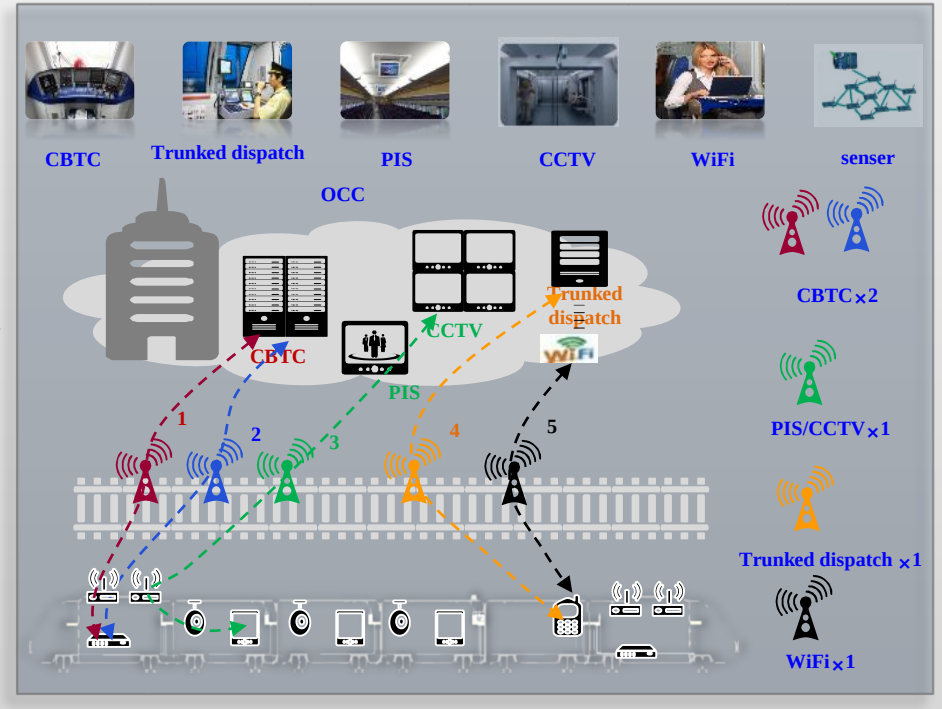
Unlicensed 5 GHz
LTE-like performance
Wi-Fi-like deployment
3GPP based, future-proof

A General Comparison

LTE-U comprehensive carrying system

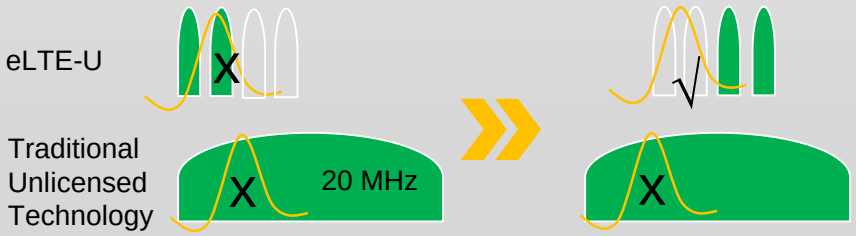


General carrying net

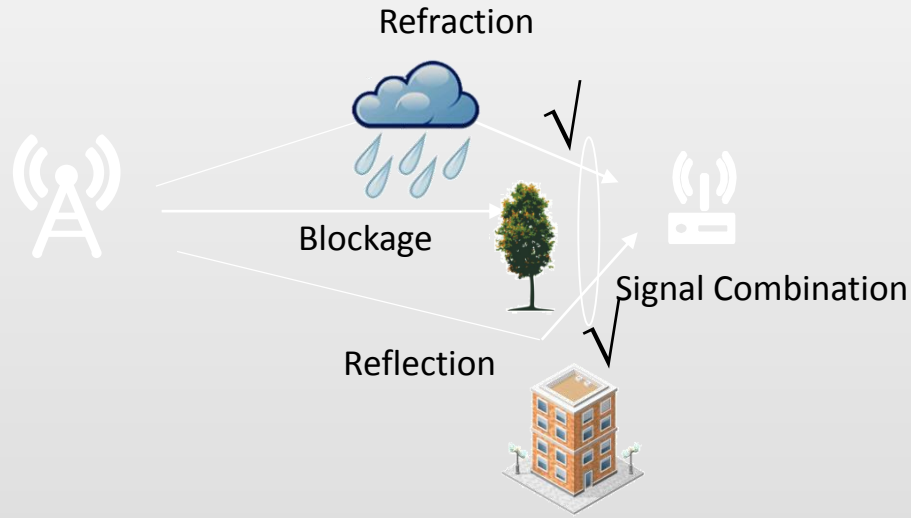


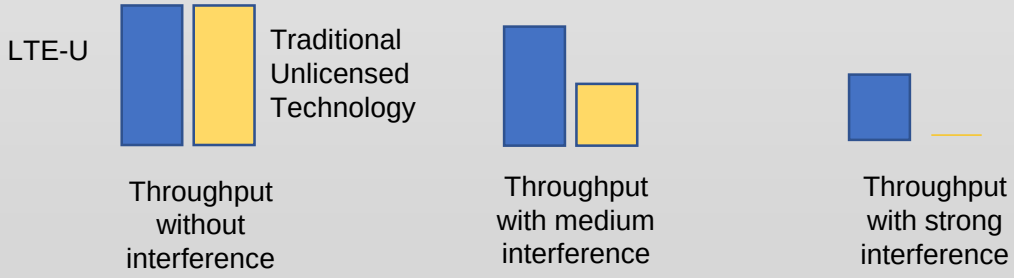
Strong Anti-interference Capability

- 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

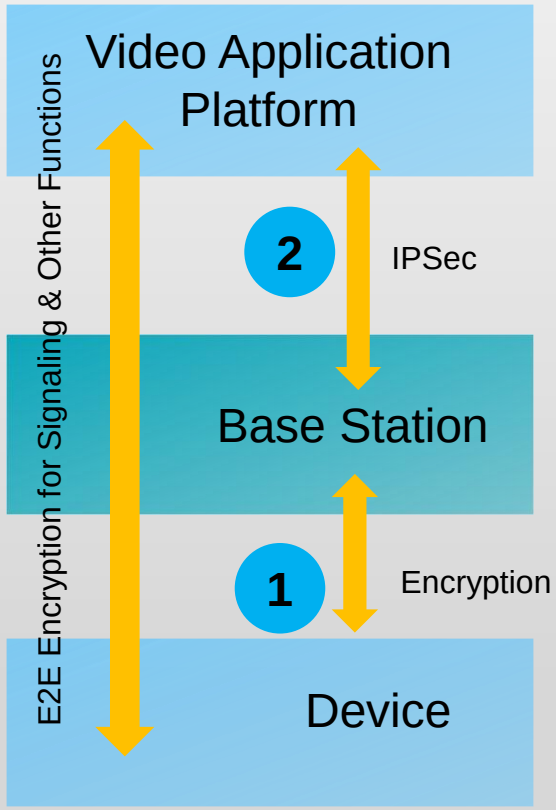




Dense Cities:
LTE-U throughput drop: 20%
Traditional unlicensed technologies: 50 to 70%

Strong Interference:
LTE-U throughput drop: 30%
Traditional unlicensed technologies: unable to establish a connection

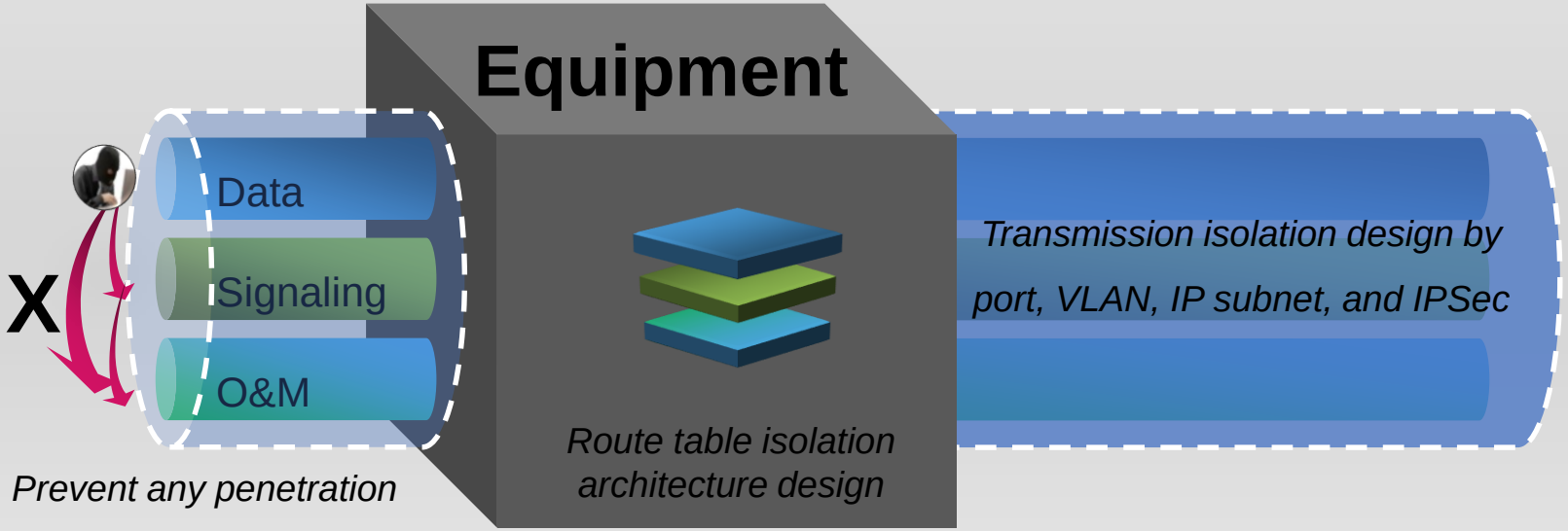
E2E Encryption Ensures Network Security



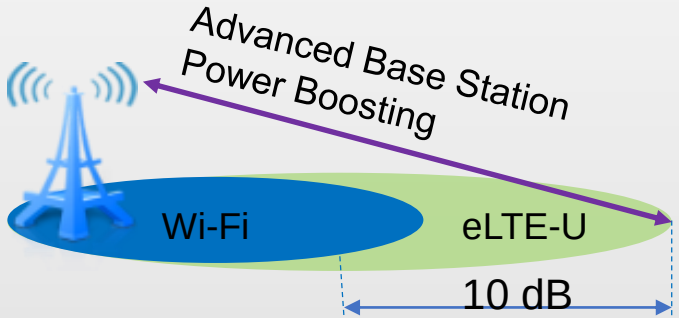
1 Air-interface Encryption

2 IPSec

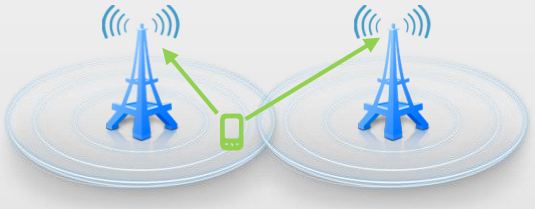
- Dual authentication between device and Base station
- IPSec ensures security between Base station and network server



Additional Benefits

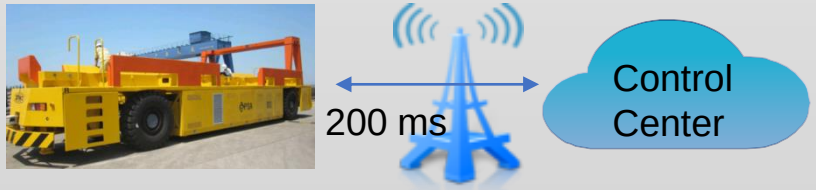


Two to three times larger coverage

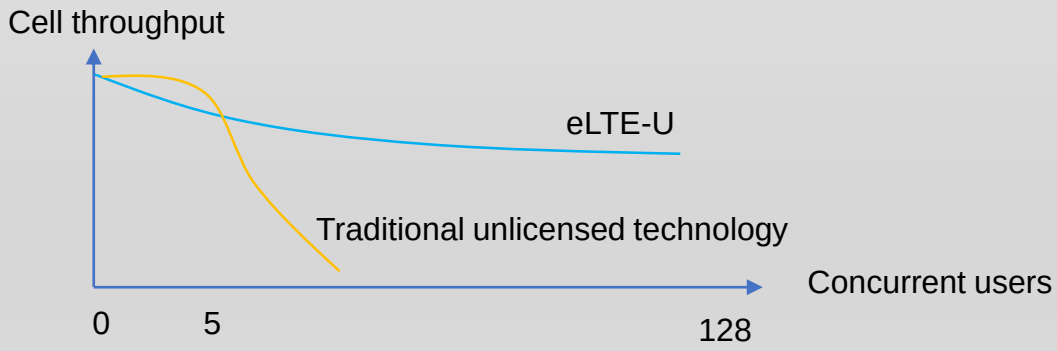


Base Station Spacing
LTE-U: 700 m, WiFi: 200 m

Capable of 100 mph
handovers without package loss



Train positioning communicated 5 x per second



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.

 eCore (3U)	 eCore (1U)
200,000 users	10,000 users
3,000 base stations	100 base stations
24 Gbit/s	2.5 Gbit/s
130.5 mm x 442 mm x 675 mm	43.6 mm x 442 mm x 310 mm

AirNode

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

eAN3810A

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

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

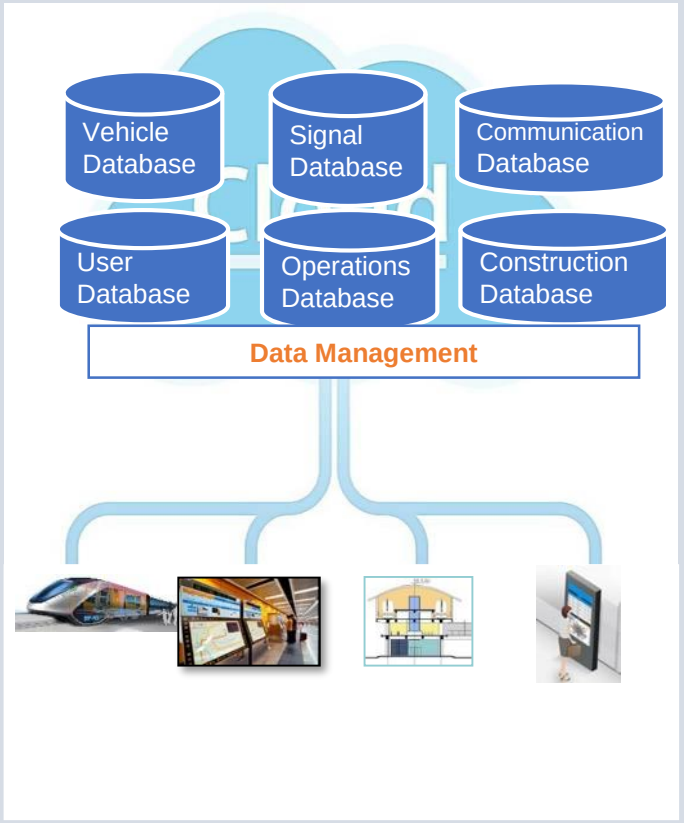
Mini-PCIe

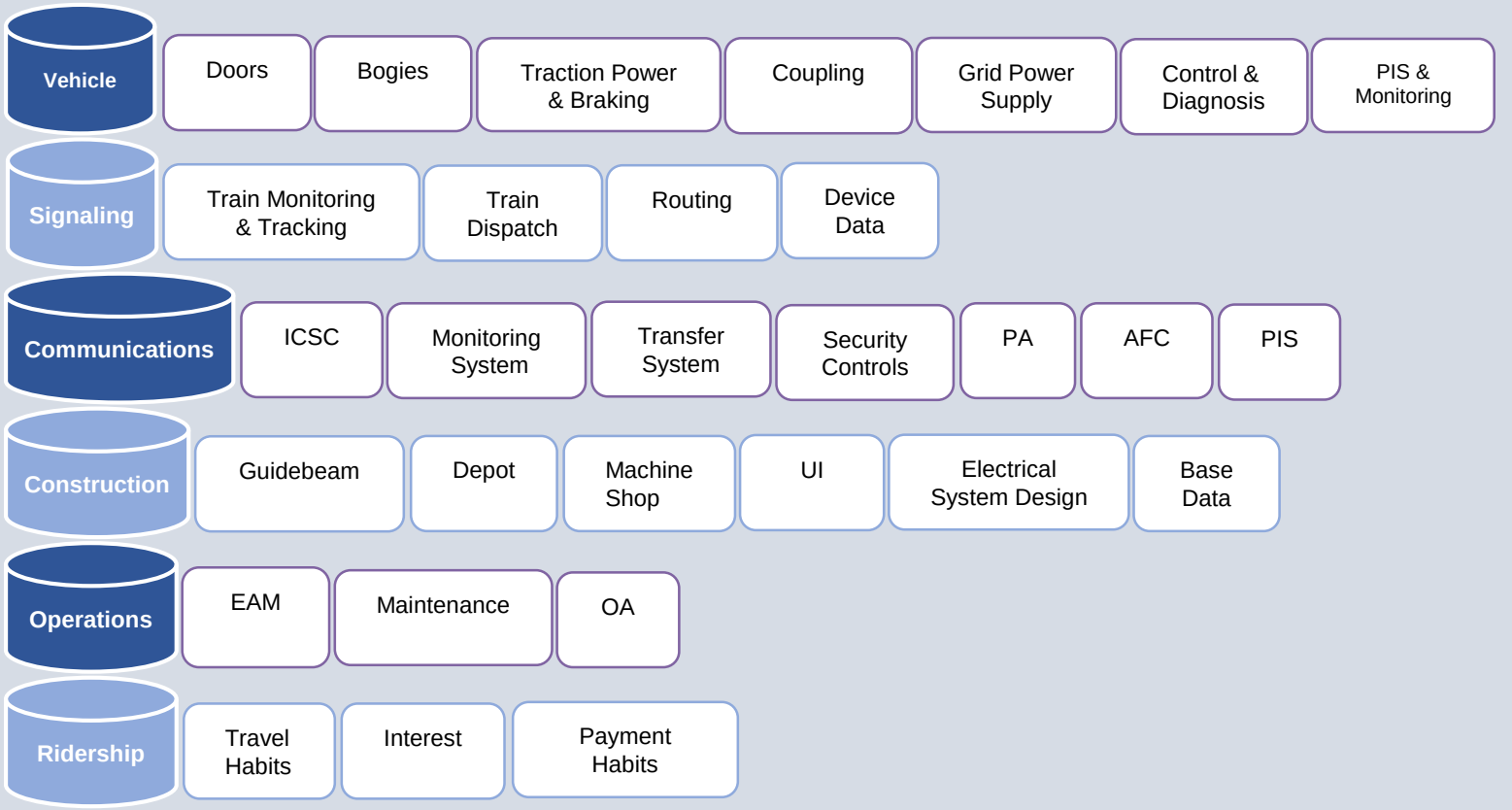
Size: 50.95 mm x 30 mm x 4.75 mm
Weight: ＜ 20g
Port: Serial/USB Port
Power: DC 3.3V

Real Time Data, All in One Place

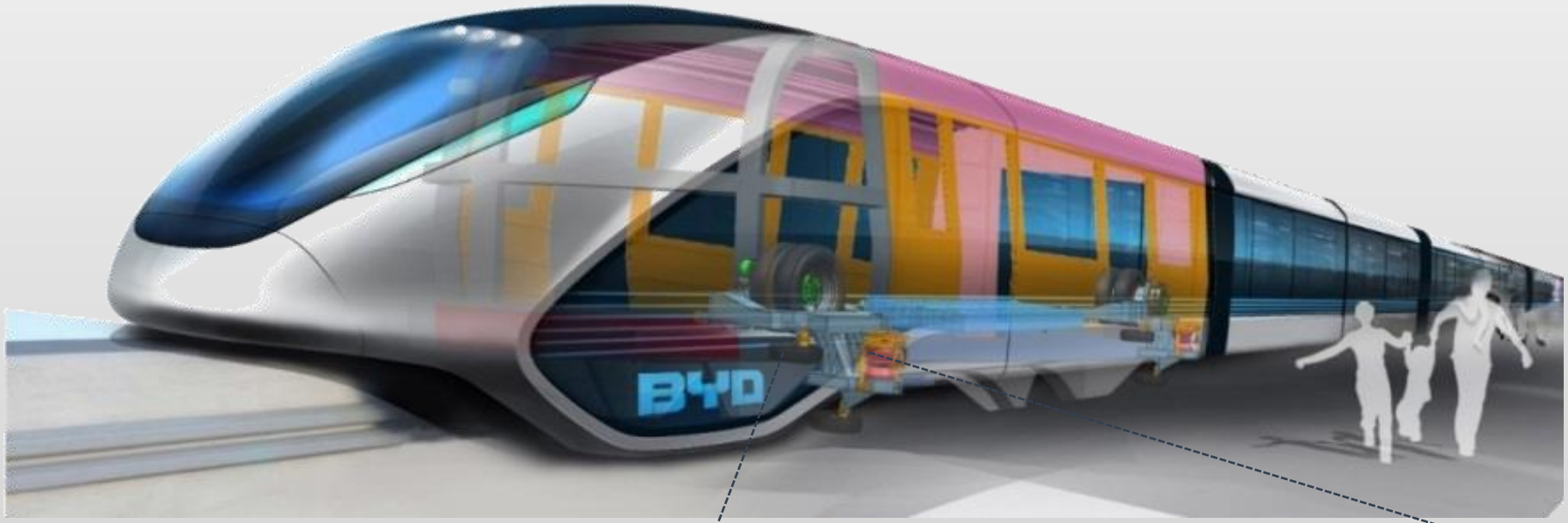
Our Cloud Network

- 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

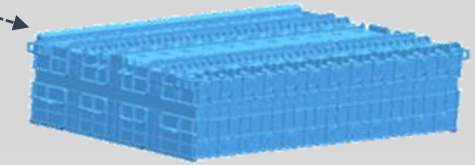




Energy Management

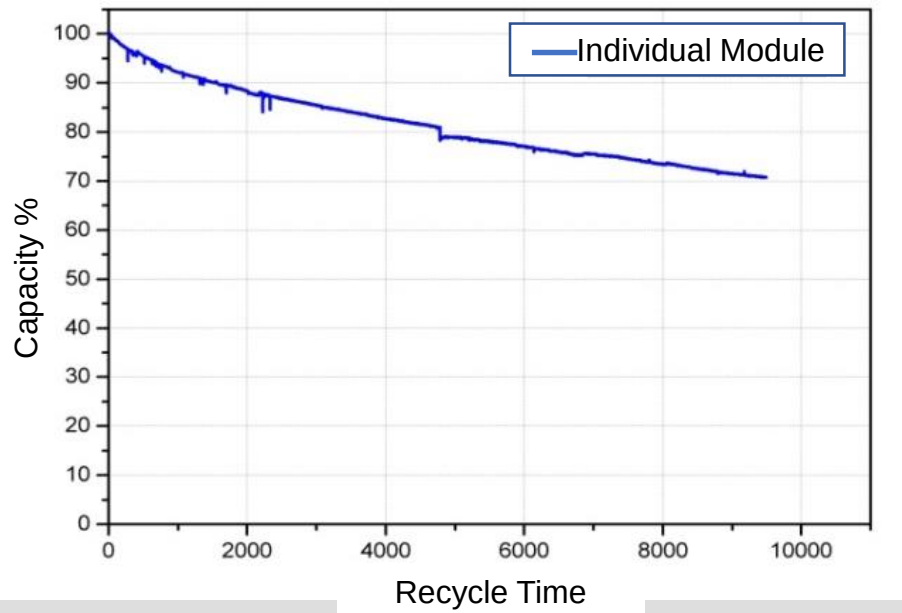


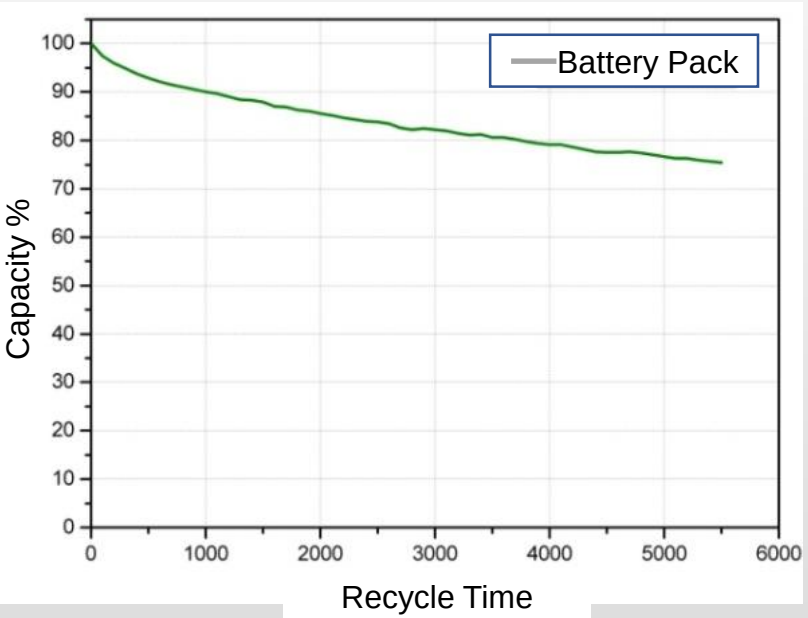
Energy Regeneration & Wayside
Battery Energy Storage



On-Board Batteries

Life Cycle Testing

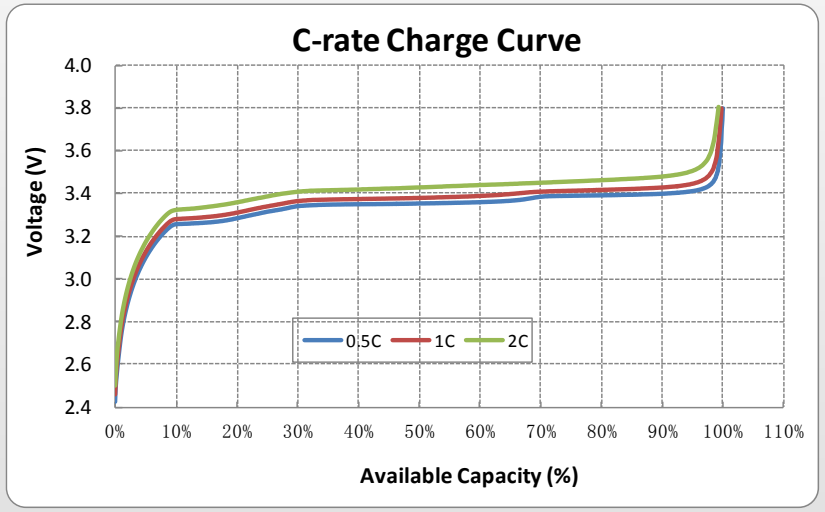


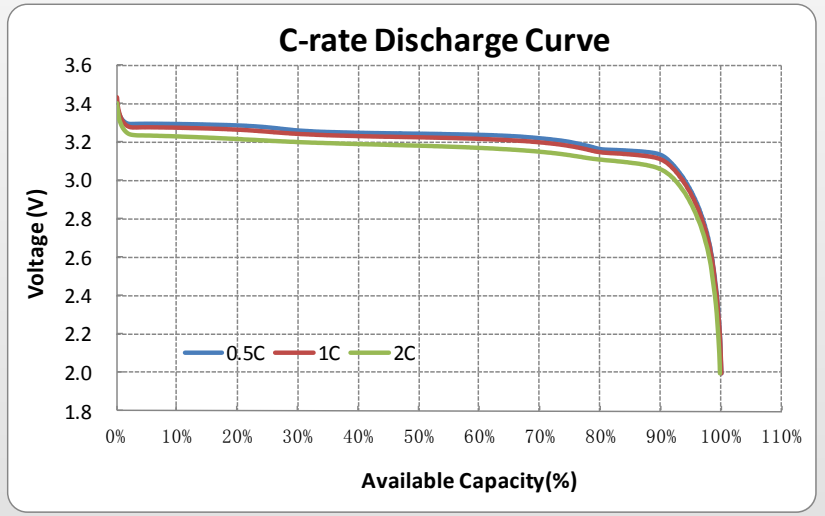


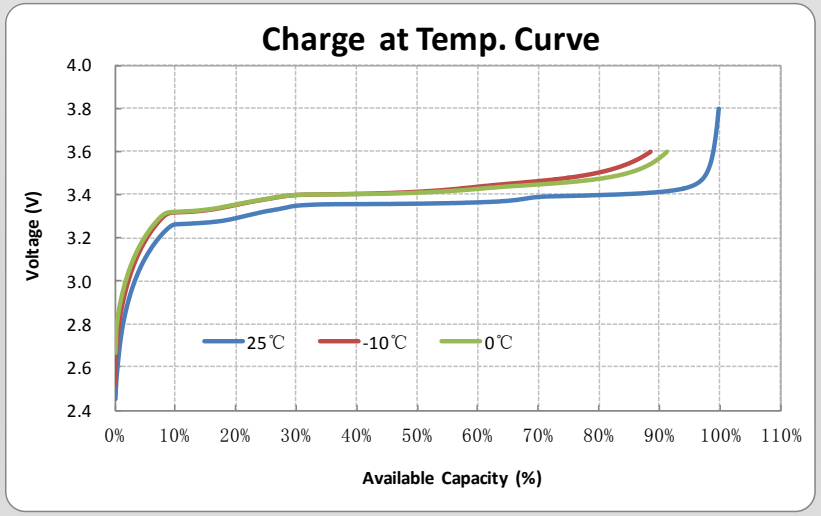
Test method: 1C/1C@25℃，100%DOD

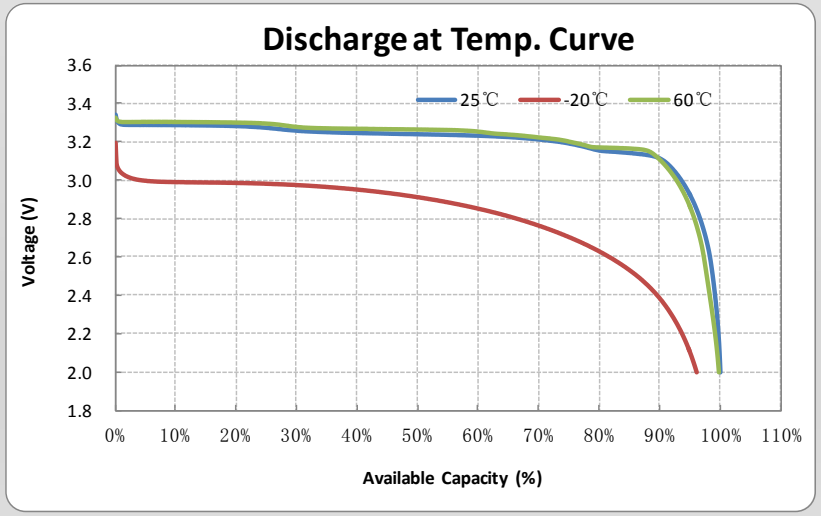
- After 9,500 cycles, the battery capacity still remains at 70.7%. The degradation curve is also much more stable than other chemistries.
- Whole vehicle packs (with multiple modules) have been tested under continuous load, raising the surface temperature of the modules to 40 ° C. However, even under these harsh conditions, the capacity has remained at over 85% after 2,000 cycles, and over 75% after 4,000 cycles.

2.6 Efficient Charge-Discharge Performance







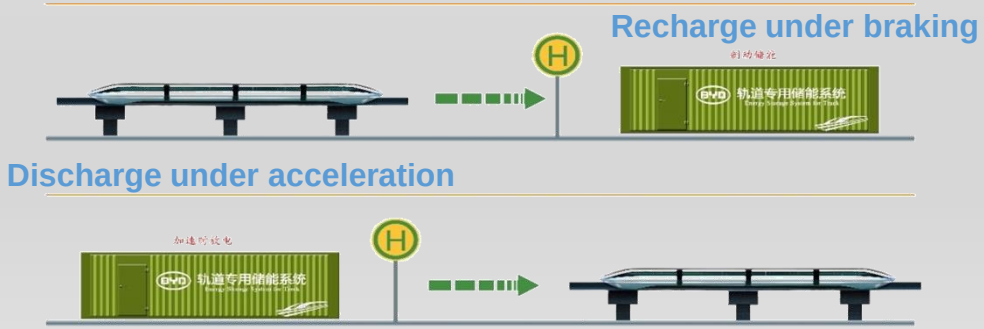


Onboard Backup Batteries

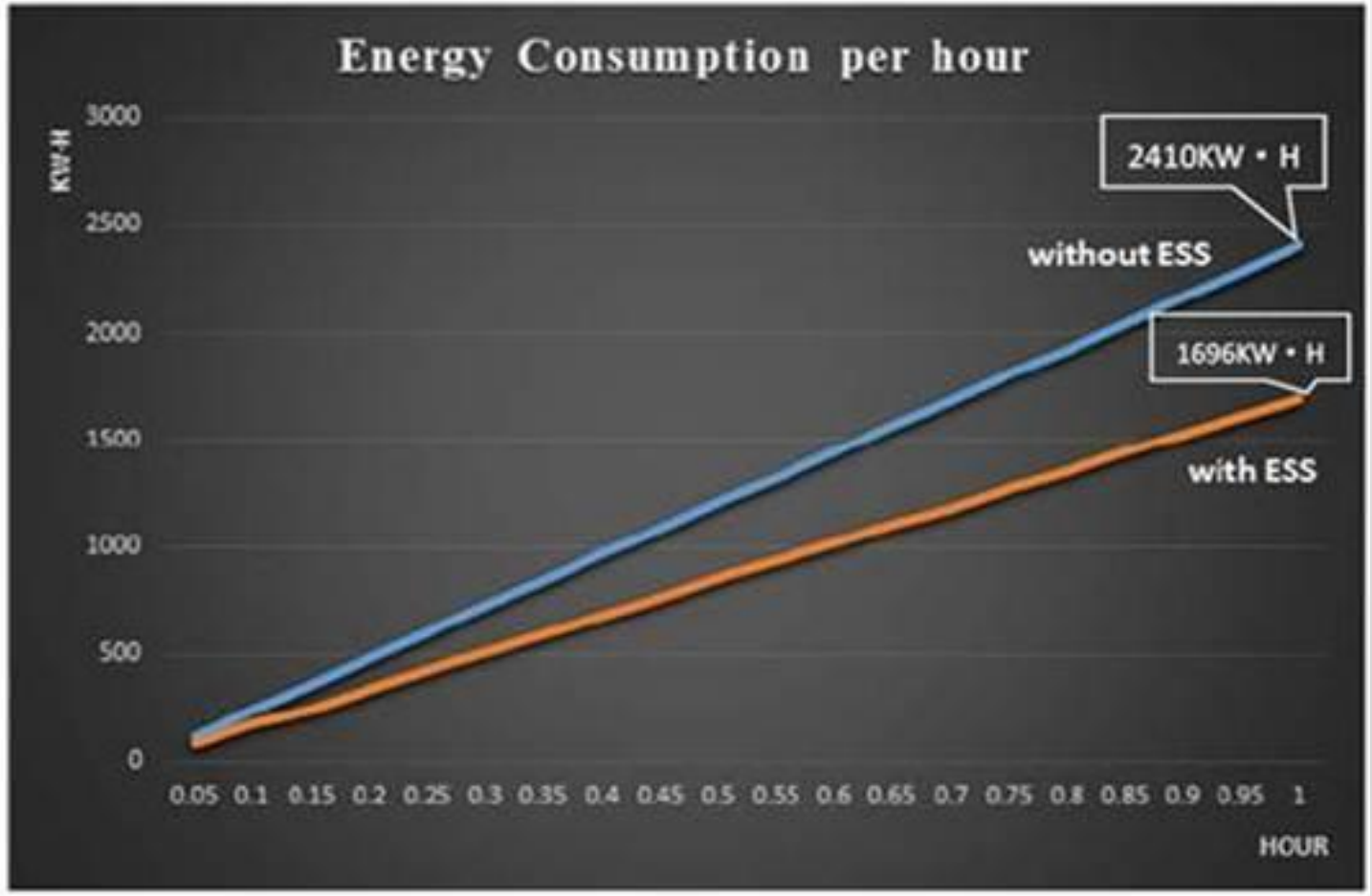
- Onboard batteries serve two purposes:
  - Provide backup traction power in event of regional power outage
  - Eliminates need for power rail in maintenance facilities
- 16 kWh capacity, 3.1 mi range

Energy Regeneration & Wayside ESS

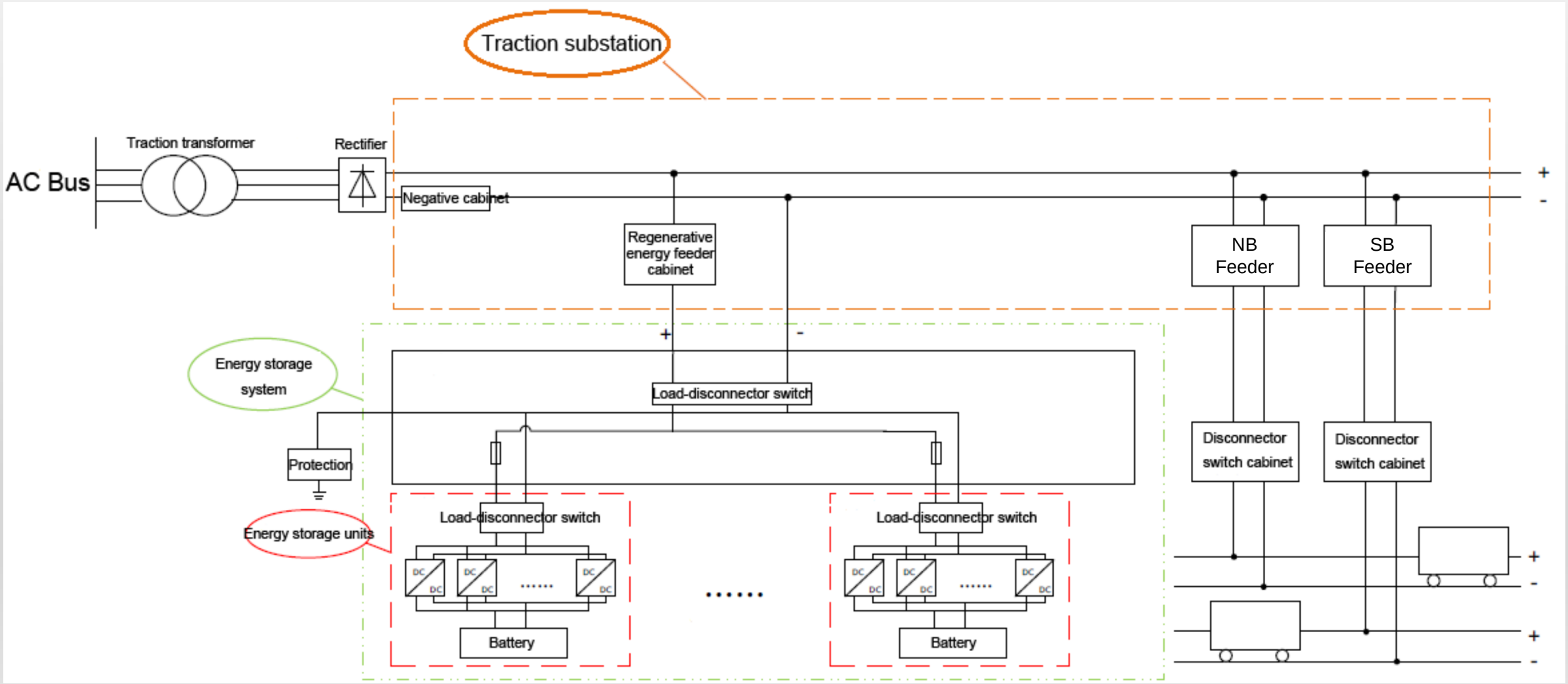
- Wayside ESS Serves two purposes:
  - Reduction in system energy consumption
  - Net voltage stabilization
- Typical installation is 1 MWh of capacity
- Spacing is approximately 2 miles apart
  - Depends ultimately on alignment conditions



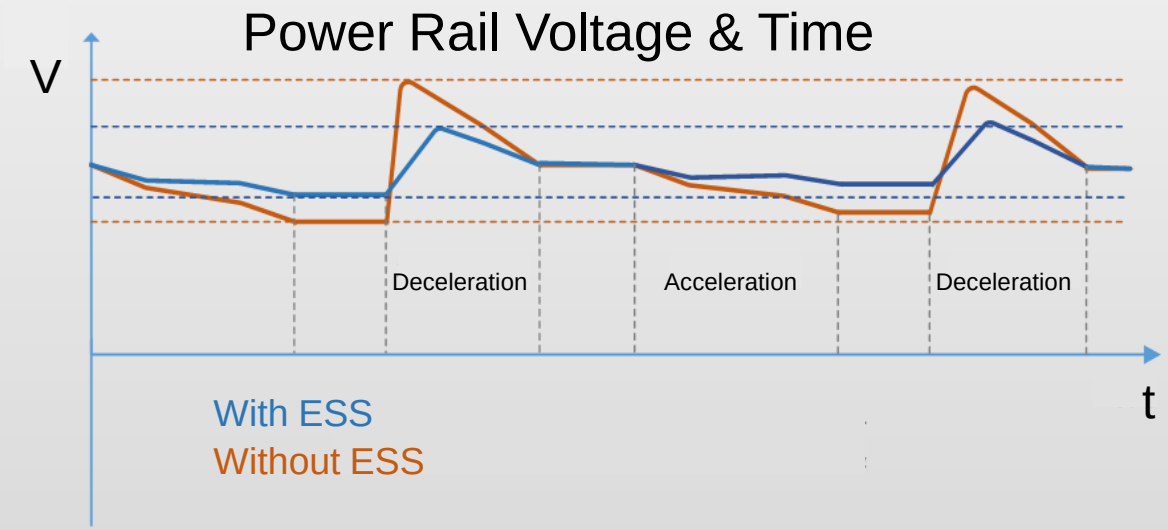
Reduced Energy Consumption

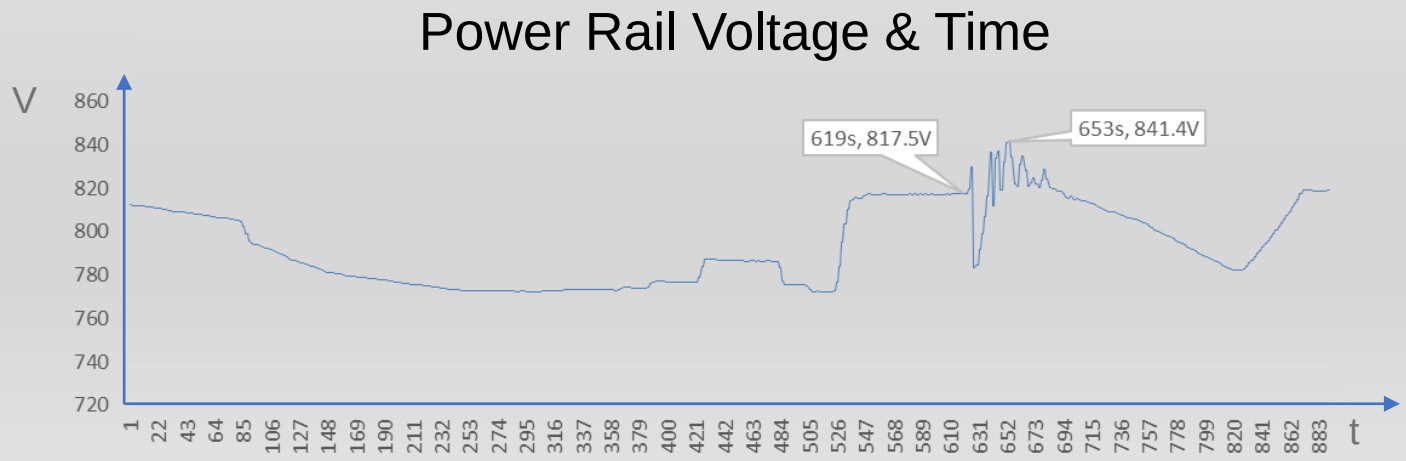


General Layout



Net Voltage Regulation





Thank you!