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Wireless IoT for Rural Use Cases

A Technical Paper Prepared for SCTE by

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1. Abstract

Smart cities and communities is a concept that is gaining more attention because of its potential to enhance citizens' lives and make cities and communities more efficient. Rural America can also benefit from leveraging new technologies like IoT (Internet of Things) and Fixed Wireless Access (FWA) to achieve better operational efficiencies.

In this paper we present findings in a Proof of Concept (PoC) project that demonstrates how technology can help an equestrian farm transform into a smart farm. We discuss the details of connecting the farm with high-speed broadband using FWA in the Citizens Broadband Radio Service (CBRS) frequency band then meshing the barn with high-speed Wi-Fi using Point-to-Multipoint unlicensed band.

Within the project, we also deployed LoRaWAN technology to provide early-warning detection of potential illness in the horses on the farm through the use of a water intake monitoring solution in addition to LoRaWAN environmental sensors installed to monitor the horses' surroundings. Another use case is deploying a mix of LoRaWAN and video analytics to detect unauthorized access to facilities.

2. Introduction

The Wireless Technologies R&D team at Charter is executing a PoC trial at a local Colorado Equestrian Farm ("Farm") to ascertain the viability of IoT technology through a variety of Smart Farming use cases, using multi-access technologies, including access technologies such as LoRaWAN, FWA in CBRS, Wi-Fi, and application technologies like video surveillance and license plate recognition.

The primary goals of the Smart Farming use cases include:

- Providing early warning detection of potential illnesses in the horses on the farm through the use of a water intake monitoring solution.
- Improving security on the farm through LoRaWAN sensor monitoring and alerting and video surveillance.
- Providing Spectrum Internet ® Wi-Fi connectivity at the Farm

In this paper, we will describe the Farm layout, which is essential in the design of the system, followed by the logical network setup description. Both the CBRS main FWA connectivity to the Farm as well as the wireless mesh connectivity to the different barns are detailed in the next section along with the broadband use case of video surveillance. Next, we will describe the IoT network based on LoRaWAN and the associated use cases for the farm. Finally, we will conclude with the summary and next steps in the research and PoC.

2.1. PoC Venue – Equestrian Farm

The PoC venue is an Equestrian farm outside of the Denver area. Overview:

- 120 Acres
- 55 Total Horses
- 3 Barns – used to stable horses (includes both leased stalls and leased horses)

  - Main barn attached to indoor training arena
  - Upper barn located 200 feet southeast of the main barn
  - Lower barn located .25 miles south of main barn
- Large indoor training arena attached to main barn
- Outdoor training arena
- Outdoor horse walker
- 4 Pastures
- Security gate at entrance with minimal security
- Farm is set up on a hill with line of site to a CBRS FWA RAN (Radio Access Network) at Charter's Spectrum's CTEC office in Englewood

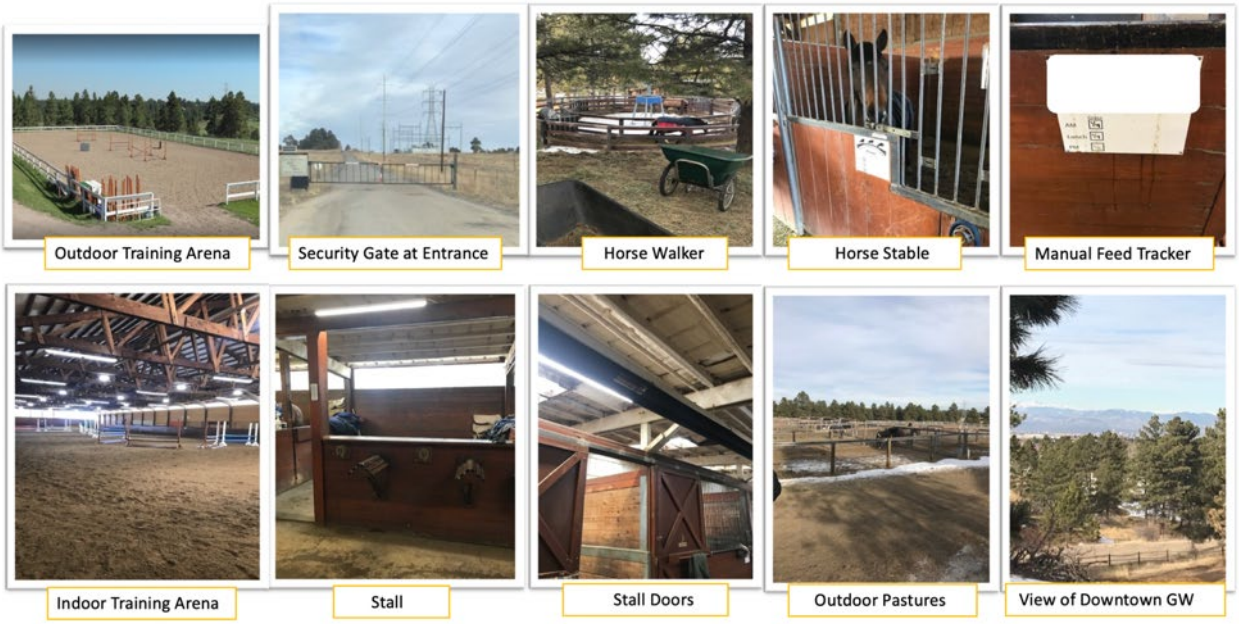

Figure 1 - Farm areas

3. Use Cases and Utilized Solution

The following figure depicts the logical network setup.

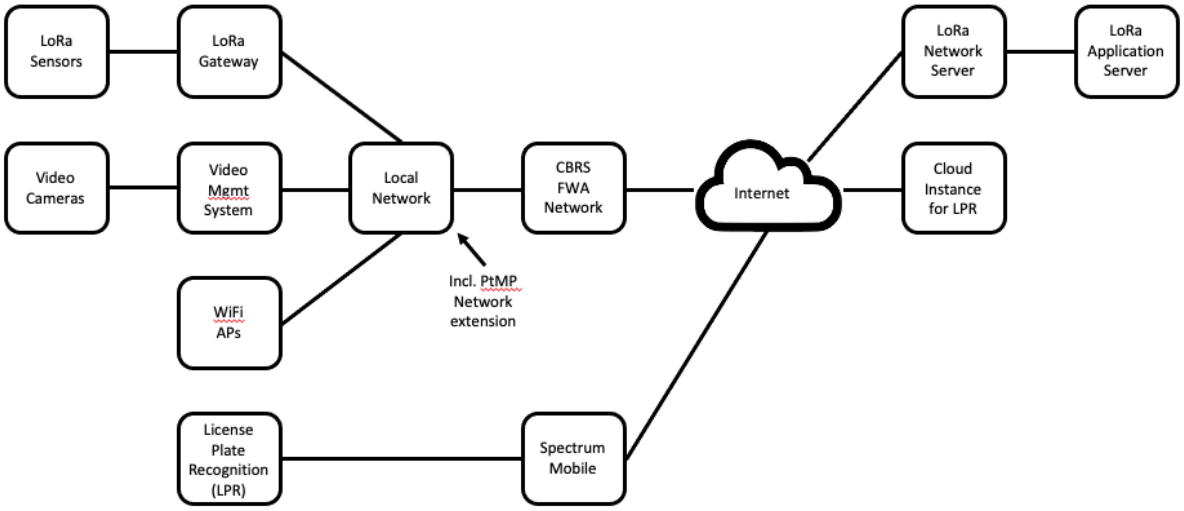

Figure 2 - Logical Network Setup

3.1. Internet Backhaul – CBRS Fixed Wireless Access

As a main 'anchor' to the internet, a Fixed Wireless Access link to the local Charter CBRS test network is utilized. The receiving eNodeB is located at Charter's CTEC1 building (5.5 miles away). Since line-of-sight conditions are available, the achievable throughput performance is close to ideal.

The 'FWA access link' is primarily used to transport traffic to the LoRaWAN network and application server, end-user internet backhaul via the Wi-Fi access point and other equipment cloud portals, but also provides the option to retrieve video streams from the local video management system. The License Plate Recognition system will have internet connectivity via Spectrum Mobile™ service.

Due to the superior Radio Frequency (RF) conditions and achievable performance results, the link to CTEC was selected.

Main Barn to CTEC Tower					
PCI	Distance	SINR	RSRP	Download	Upload
120	5.5 Miles	26 dB	-92 dBm	240 Mbps	11 Mbps

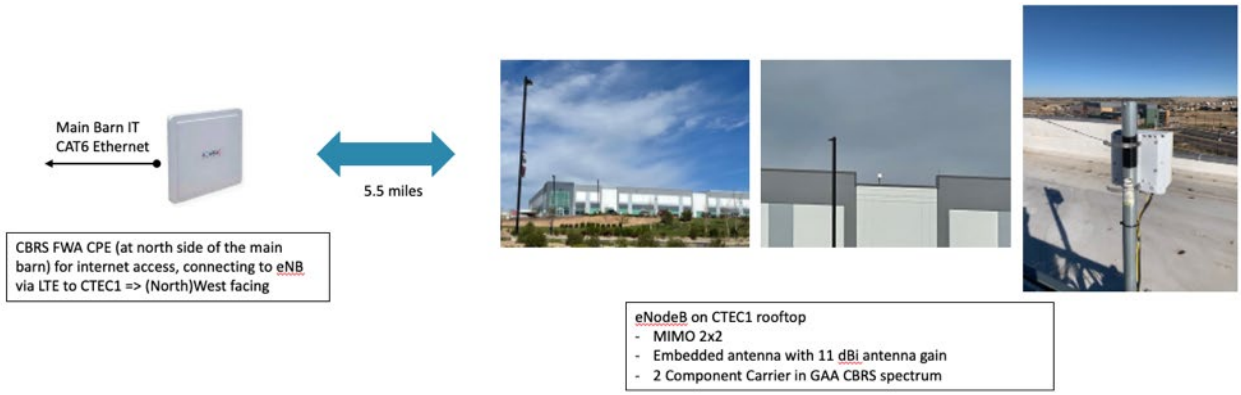

Figure 3 - eNodeB deployment at Charter CTEC1 building

3.2. Local Network Extension and Access for Farm Owner and Customers

Due to the distribution of Farm buildings – main/upper barns and owner's house – a wireless extension of the local network is required, mainly to achieve the following:

- Transport of the camera feeds from the upper barn stalls to the video management system (VMS) at the main barn
- Remote Wi-Fi access point at the farm owner's house to be able to access the system

For that purpose, a Point-To-Multipoint unlicensed 5GHz wireless system was chosen. The Base Station is mounted at the main barn and connected to the main distribution network switch. The subscriber units are installed at the upper barn and the farm owner's house.

In addition to the Wi-Fi AP at the farm owner's house, another unit is deployed inside the main barn for access to the network.

3.3. Video Surveilance

For the purpose of giving the option to the Farm owner and farm personnel to visually monitor designated areas in the farm complex, the following areas were equipped with cameras and connected to a video management system with integrated DVR:

- 4 horse stalls in main barn
- 5 horse stalls in upper barn
- Indoor training arena (4 cameras total) in the main barn
- Outdoor facing horse walker

3.3.1. Use Case 'video surveillance horse stalls':

Farm owners and personnel have the ability to remotely monitor the conditions of select horses for improved welfare and security. In the future, this could be extended to provide the same access to the horse owners. Additionally, processing the captured and stored video feeds allows for implementation of further analysis and detection of unusual horse behavior via AI (Artificial Intelligence) and ML (Machine Learning).

Figure 4 - Horse Video Surveillance

3.3.2. Use Case 'video surveillance indoor training facility':

Farm owners and personnel have the ability to detect abnormal behavior or 'not permitted' jumping based on time (after hours), in combination with installed LoRaWAN proximity sensors, and general remote monitoring of activities.

Figure 5 - Training Facility Video Surveillance

3.3.3. Use Case 'video surveillance outdoor horse walker':

Farm owners and personnel have the ability to remotely monitor activities at the outside horse walker, in combination with LoRaWAN sensors, in order to detect equipment malfunctions, horses escaping or other general remote monitoring of activities.

Figure 6 - Horse Walker Video Surveillance

3.4. LoRaWAN® Network and Sensors

For the purpose of monitoring conditions and environments in the Farm area, a LoRaWAN network setup consists of various sensors and an outdoor gateway, interconnecting via the internet to a network and application server. Sensors that are part of the solution include:

- Open/close door for monitoring the selected horse stalls
- Temperature and humidity in main, upper and lower barns and TAC room (contains equipment for the solution)
- Proximity sensors for training facility and outdoor horse walker (use cases described earlier)
- Water consumption monitoring. This sensor solution consists of a water meter, which is in line with the water supply and the water bucket for the horse (automatically refilled via a floating valve) and connected to a LoRaWAN pulse sensor.

Figure 7 - Water meter and LoRa pulse sensor solution

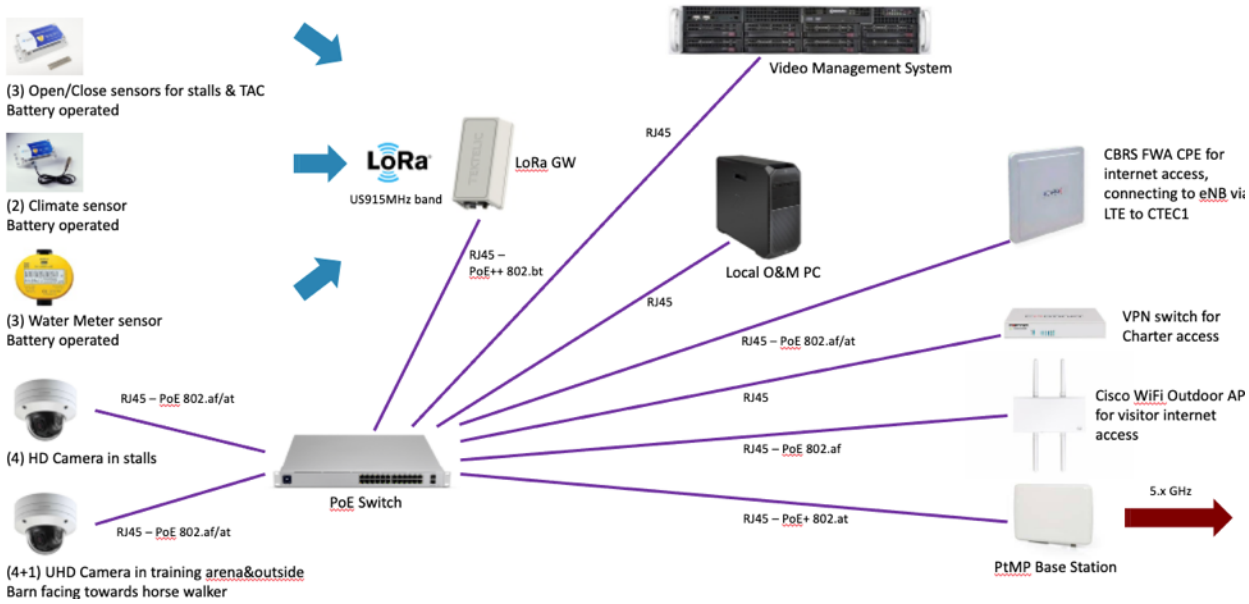

Figure 8 - Connectivity diagram example, here in the main barn

3.5. License Plate Recognition at Gate Entrance

The purpose of the license plate recognition (LPR) is to provide the Farm owner with the ability to monitor and track access, with dates and times, of visitors for potential later proof of entrance for those who entered the Farm area. As additional enhancement for the future, the LPR system could be linked to the gate control via a white/black list control.

Figure 9 - Example of outdoor LPR install

Figure 10 - Location of gate and existing poles

The LPR system is installed in close proximity to the gate, which is approximately 0.5 miles away from the Farm building complex.

The processing of the license plate recognition is done at the edge in a self-contained battery and solar powered system. The processed data is sent to a cloud portal via a cellular (using Spectrum Mobile service) link.

4. Conclusions and Next Steps

The proof of concept activities have already demonstrated that the use of hybrid wireless technologies combined with data processing at the edge and in the cloud is extremely helpful in a rural farm environment for its day-to-day activities. The trial will continue and learnings from the end users - farm owners and personnel - will be used to improve the overall solutions. Additionally, other use cases or enhancements to the existing use cases will be made as needed.

Abbreviations

BH	Back Haul
CBRS	Citizens Broadband Radio Service
CBSD	Citizen Broadband Radio Service Device
CPE	Customer Premisis Equipment
EPC	Evolved Packet Core
FWA	Fixed Wireless Access
GAA	General Authorized Access
IoT	Internet of Things
LoRaWAN	Long Range Wide Area Network
LOS	Line Of Sight
LPR	License Plate Recognition
LTE	Long Term Evolution
MIMO	Multiple Input Multiple Output
PCI	Physical Cell ID
PoC	Proof of Concept
PoE	Power over Ethernet
PtMP	Point to Multi Point

RAN	Radio Access Network
RF	Radio Frequency
RSRP	Reference Signal Received Power
SAS	Spectrum Access System
SINR	Signal to Interference plus Noise Ratio
UE	User Equipment
VMS	Video Management System
VPN	Virtual Private Network

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