Wyoming Roadside Network and Backhaul Upgrade

Presenters

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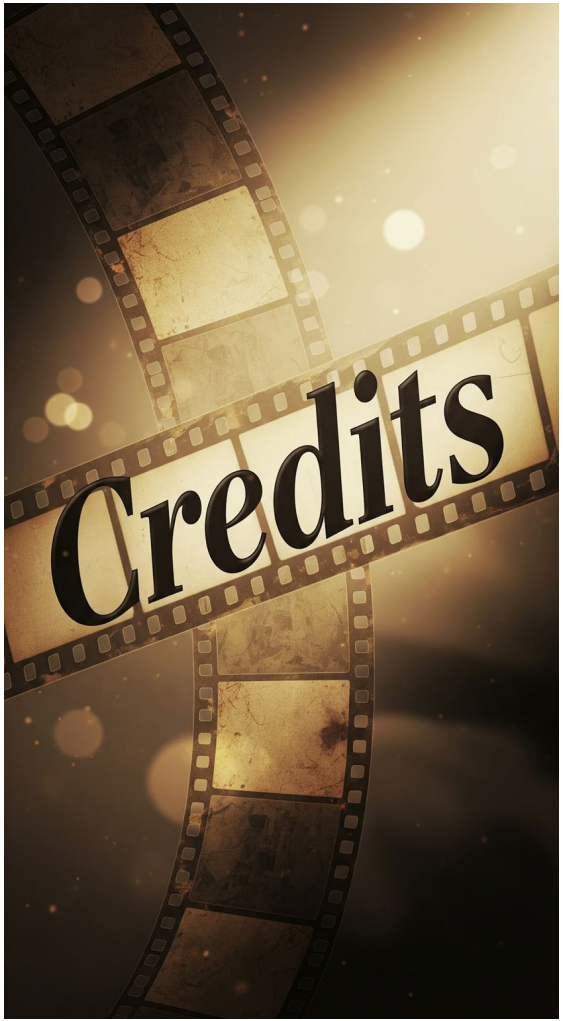


Credits and resources

Paul Anderson 2009 presenter

Mark Kelly 2017 Presenter

WYDOT ITS

Neara Consultings

State of Wyoming Enterprise Technology Solutions (ETS)

Acronyms

SAR - Service Aggregated Router
MW - Microwave
FiDi - Site name the first and second letters of the complete name
PtP- Point to Point
PtMP - Point to Multi-point
MPLS - Multi Protocol Label Switching
PoE - Power over Ethernet
ITS - Intelligent Transportation Systems
VRF - Virtual Routing and Forwarding
ETS - Enterprise Technology Solutions
OSPF - Open Shortest Path First
VPN - Virtual Private Network
WYDOT - Wyoming Department of Transportation
E-Pipe - Raw Ethernet Pipe

We will be discussing

Background and History

Innovative pioneers along the way

Equipment

Successes

Short falls

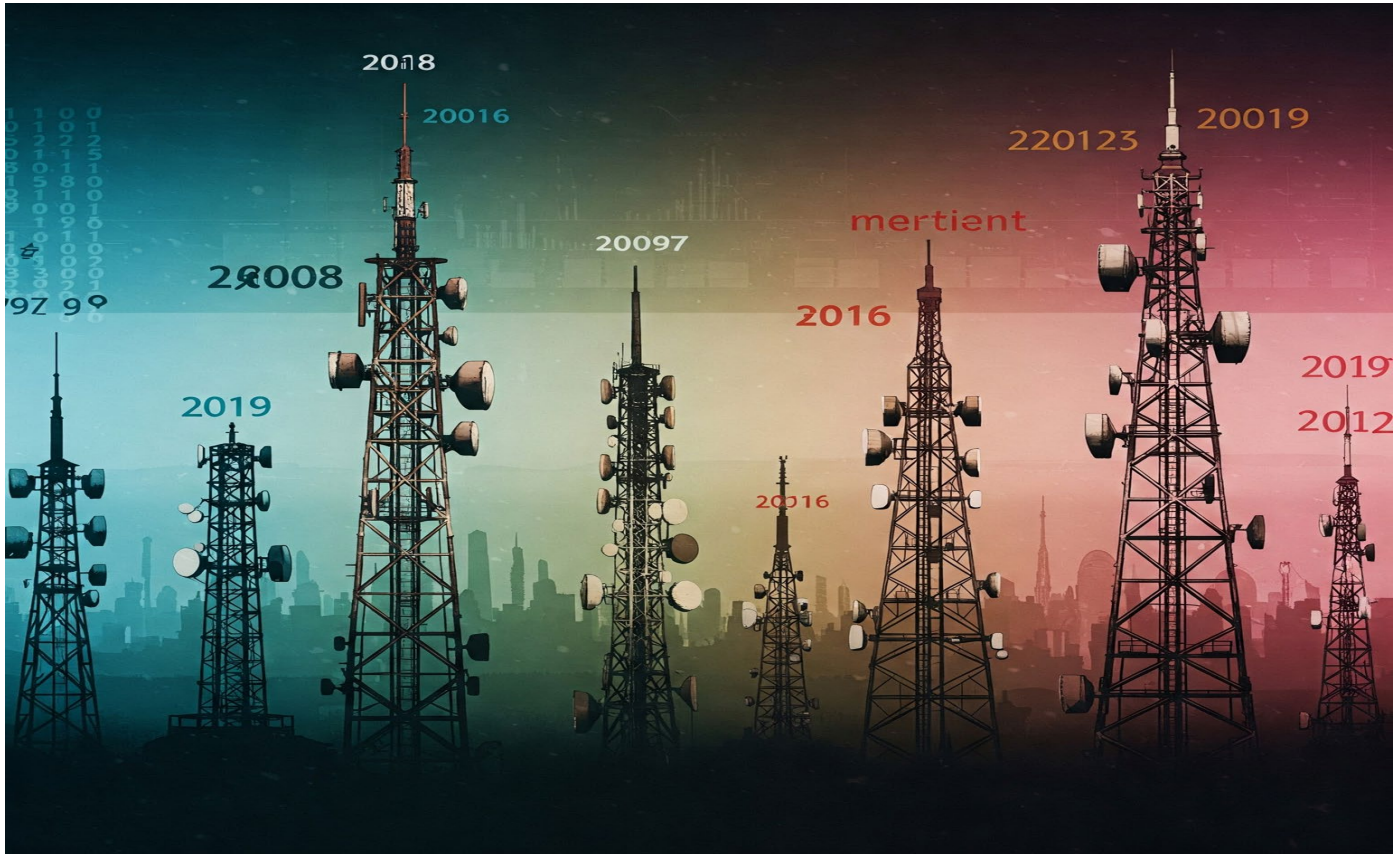
Redesign

Redundancy

Pilot projects

Future

History



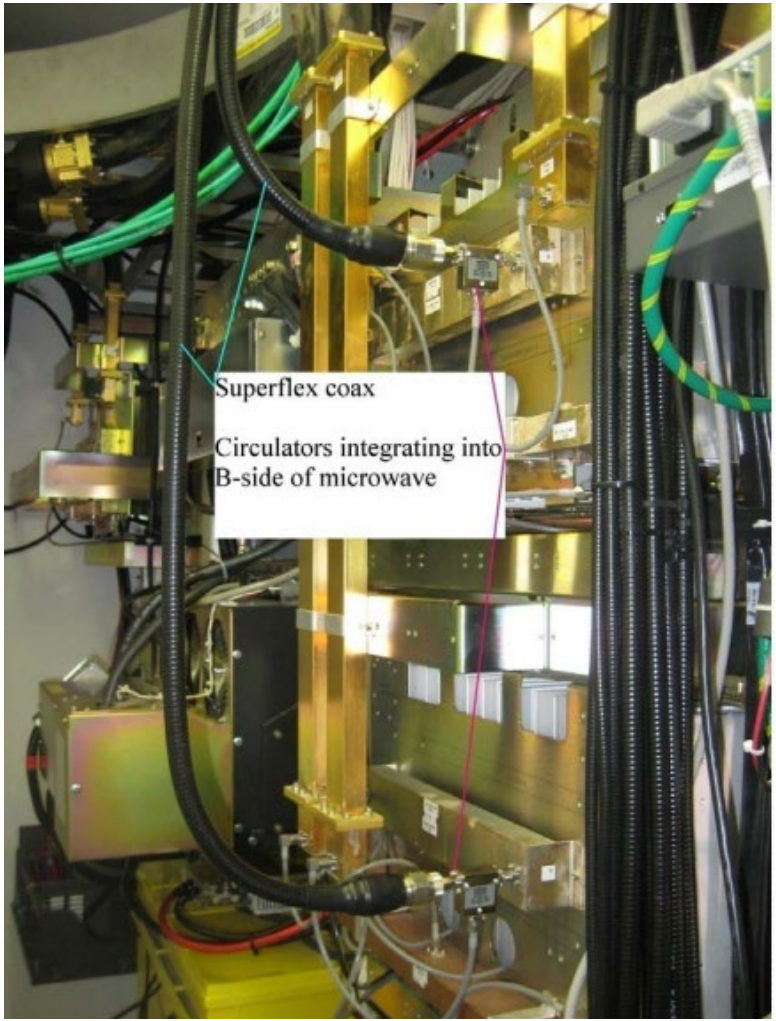
Piggybacking on MW backhaul 6 GHz dishes for Roadside Device communications on 5.8 Ghz

First use of the Microwave Emergency Communications Backhaul for Roadside devices communication was in 2008.

Paul Anderson, Who presented in 2009, developed and implemented the concept of the “Underbuild Solution” (integration into our licensed 6.0 GHz microwave infrastructure)

See presentation:

chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.westernstatesforum.org/Documents/2009/WyDOT_Andersen_EthernetIPBackhaul_6-16-09.pdf



How it worked

Uses connectorized version of radio that integrate into the microwave's "plumbing" at the transition junction using passive filters and circulators for integration on the receive side of the microwave.

First design utilized Motorola's PTP400 Radio

Evolution

Smaller, Better, Faster

Ubiquiti Bullet Radios 2014

- Fraction of the price of the Motorola radio
- No licensing to deal with
- Very small footprint
- Readily available
- Easy to setup and program
- 19.2+ Mbps vs 1.5 Mbps

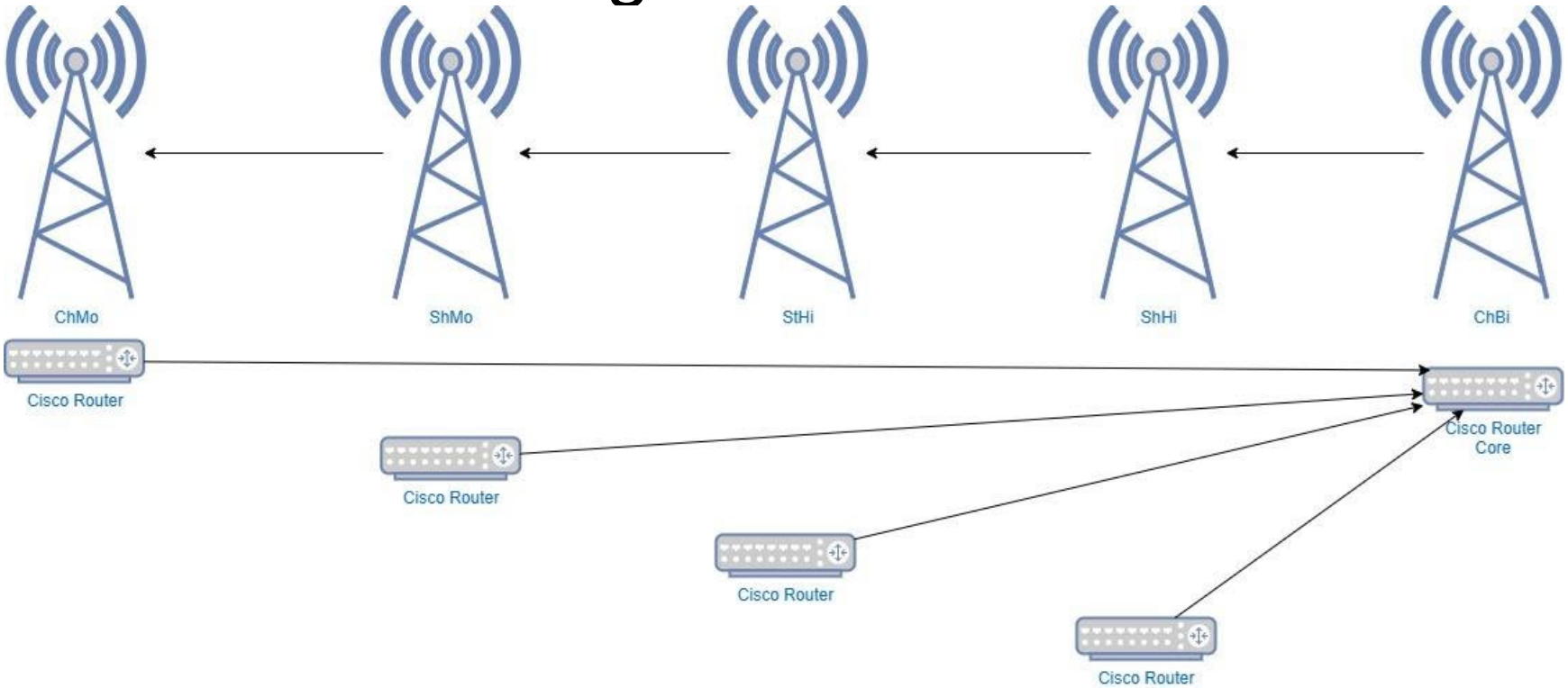
Into The “SAR”

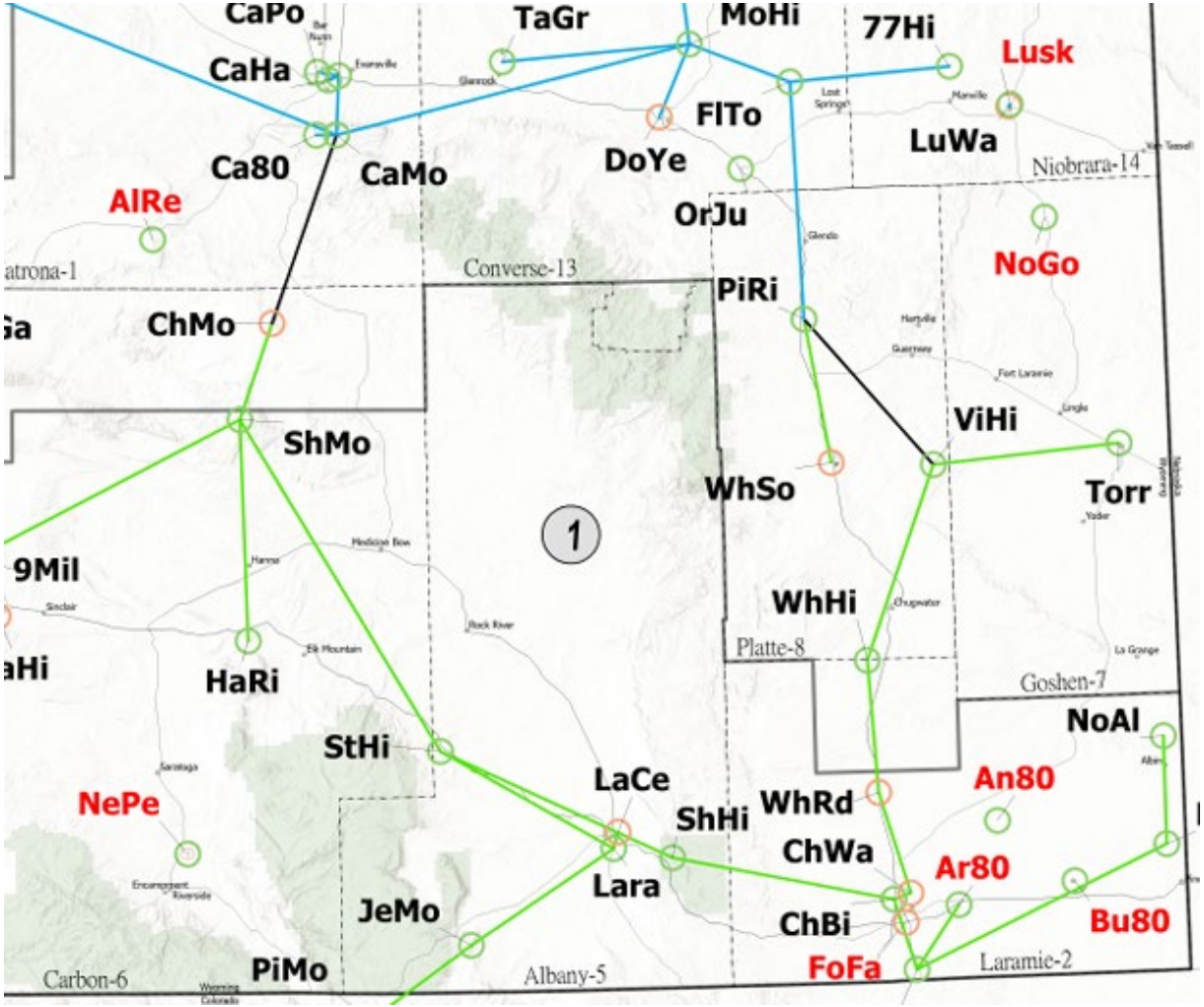
WYDOT began upgrading the P25 network to Ethernet in 2019. Microwave to Ethernet utilizing Nokias Service Aggregation Router

By removing T1 and T3 connections and migrating this to ethernet and using the Nokia SAR this allowed IP traffic for roadside to travel on the MW instead of piggybacking.

We utilized Wyoming's ETS team and reused the existing routers at MW sites. Using the SAR’s MPLS and pointing the routers to a core router in Cheyenne. Eventually working this into the MW SAR ring for limited redundancy.

Network Drawing of Existing SAR Router Configuration





Current Redundancy Loop

Success that led the way and open the door for advancement

- First long haul PtP on existing infrastructure.
- Tapping into existing 6Ghz MW and transmitting 5.8
- Use of routers to expand networks
- Use of routers and the MPLS of the SAR for a hub and spoke network design.

Shortcomings of the existing system

- Motorola PTP 400

  While robust were very expensive, have proprietary POE, large footprint, less throughput.

- Redundant loop that didn’t always work.
- Central core router a single point of failure.

Shortcomings of the existing system (cont.)

- Mix and match of radios and technology throughout

  Currently both the PTP400 and the Bullet are being used along with the microwave SAR Making this a difficult system to maintain and troubleshoot

- End of life Cisco 1941 Routers unable to handle the demands of modern networking.

Wyoming’s ITS Network Redesign

Identifying the Need

With over 200 roadside cameras, WiFi for connecting maintenance personnel to network for road reporting, another 2000 plus ITS devices, 300 Traffic signals all requiring significantly more bandwidth than ever before, it was past time. Multiple VRFs and shared networks without consistency and an aging system that was becoming harder to maintain.

Wyoming’s ITS Network Redesign

The key motivations behind the network redesign project were:

- **Dated and end-of-life equipment:** Replacing aging devices that lacked security features and were incompatible.
- **Enhanced security:** Implementing firewalls, network isolation (VRFs), and user access security measures.
- **Network isolation:** Using VRFs and smaller subnets for better security and management.
- **Redundancy:** Adding multiple communication paths for a more reliable network.
- **Network monitoring:** Implementing tools to track network and device performance.

Dated and end of life equipment

- Legacy devices that do not have built-in security
- Devices that are 20 years old on the roadside that never had much thought put into network security.
- Cisco 1941 routers being used that did not support VRFs
- Incompatibility of network equipment from many years of partial upgrades.

Enhanced security

Ingress Firewalls at Roadside

- Insure only trusted traffic entering the network from the roadside

Egress Firewalls at Roadside and handoff points

- Isolates that equipment that can not be properly protected from cyber threats so that it is only accessible from very few locations.
- Firewalls at handoff points allow us to filter out networks scans that crashes older ITS equipment.

Enhanced security

User Access Security

- Citrix for all access to the networks
- Yubikey for multi-step authentication
- Jump boxes to isolate computer connections to networks and devices

Network Isolation

Creating multiple VRFs (Virtual Routing and Forwarding)

- All communication paths on separate VRF from roadside equipment
- Smaller subnets. Each PtP network and each roadside location its own subnet. Primarily a /28 or /29
- Multiple departments maintaining the systems helps them identify who equipment is whos.
- Multiple VRFs helped with another layer of security through Wyoming's ETS and only certain user groups have access into the VRF
- With communication paths on a separate VRF allowed to create redundancy easier.

Redundancy

While still utilizing the SAR and the Emergency Communications Microwave, we started placing ETS Unified connections at roadside locations.

By utilizing routers we could create the redundancy needed to create a more reliable network.

- Using MW backhaul, Starlink, leased circuits, Wyoming Unified Network, Cellular
- Routing using OSPF
- Leveraging Site to Site VPN connections

Network and Device Monitoring

WYDOT selected Zabbix as it's monitoring platform moving away from a dated and cumbersome SolarWinds solution

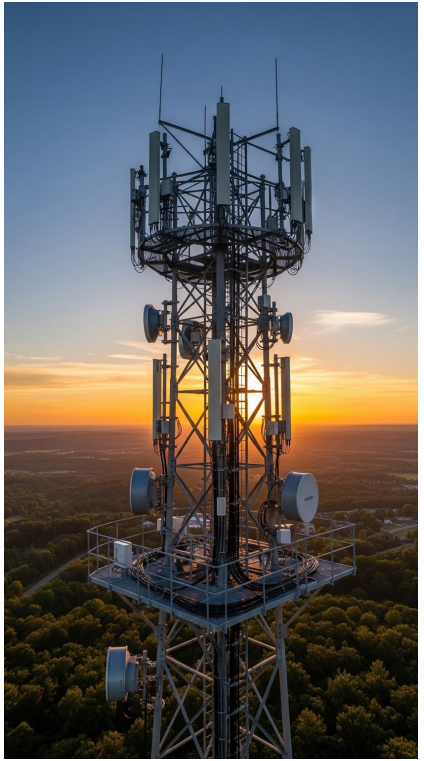
Zabbix- Open source network monitoring program capable of monitoring roadside devices, routers, radios, servers, applications, processes and more.

Mikrotik firmware and configuration is being managed through "Ansible script" that will target a given system, update the RouterOS and firmware version in the proper sequence.

Designing the New RF Network

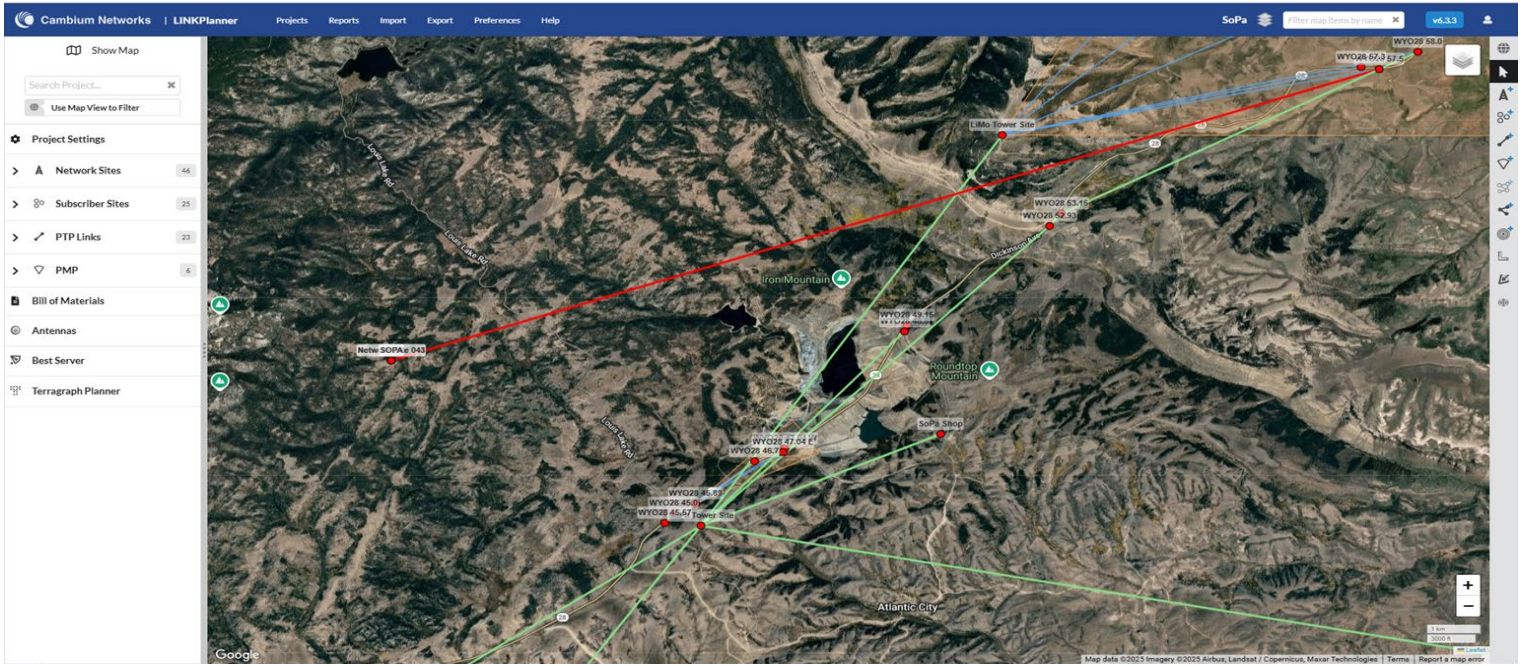
While the need to replace the equipment was inevitable we also found that we need to clean up our RF links across the State.

- Every path re-evaluated to ensure optimal connection.
- PtMP connections replacing several PtP links
- Equipment deployment reduction
- Eliminating Backhaul radios and utilizing the Emergency Communication MW paths.



Cambium Link Planner

Wydot utilizes Cambium LP for all communication paths. This allowed us to map out and record what we have installed and where.



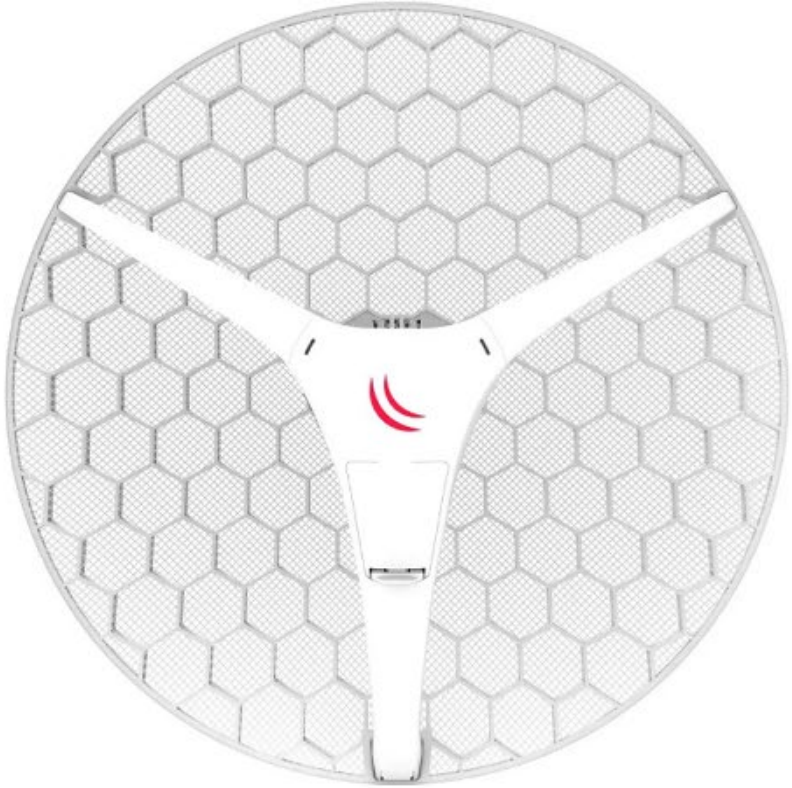
Mikrotik

MikroTik is a Latvian company which was founded in 1996 to develop routers and wireless ISP systems. At WYDOT we have used their products since 2015.

Products we use

- Routers RB5009, L009UiGS
- Radios - SXT, QRT, LHG, LHGHP, Basebox

Purpose of using Mikrotik for wireless links was to be able to use 5.8Ghz and 4.9Ghz in same radio



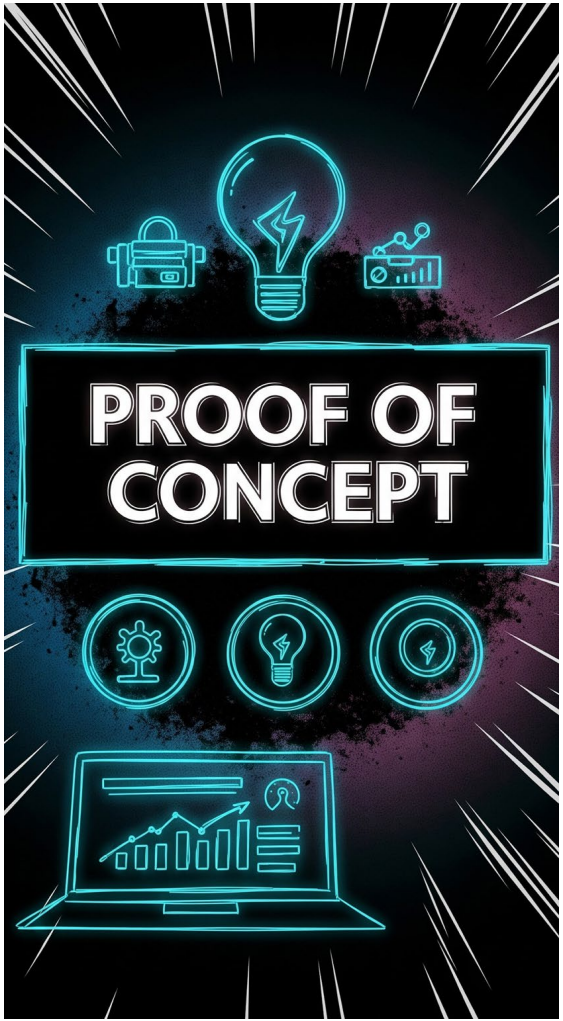
Proof of Concept

Basin Wyoming Project

A change to the microwave system we were utilizing removed all the T1 connections and our equipment was not compatible with the change. In addition ethernet upgrade to the MW was not planned for 2 years.

With no easy fix to this isolated network it was an excellent opportunity to put into action the idea we had been discussing for a few months.

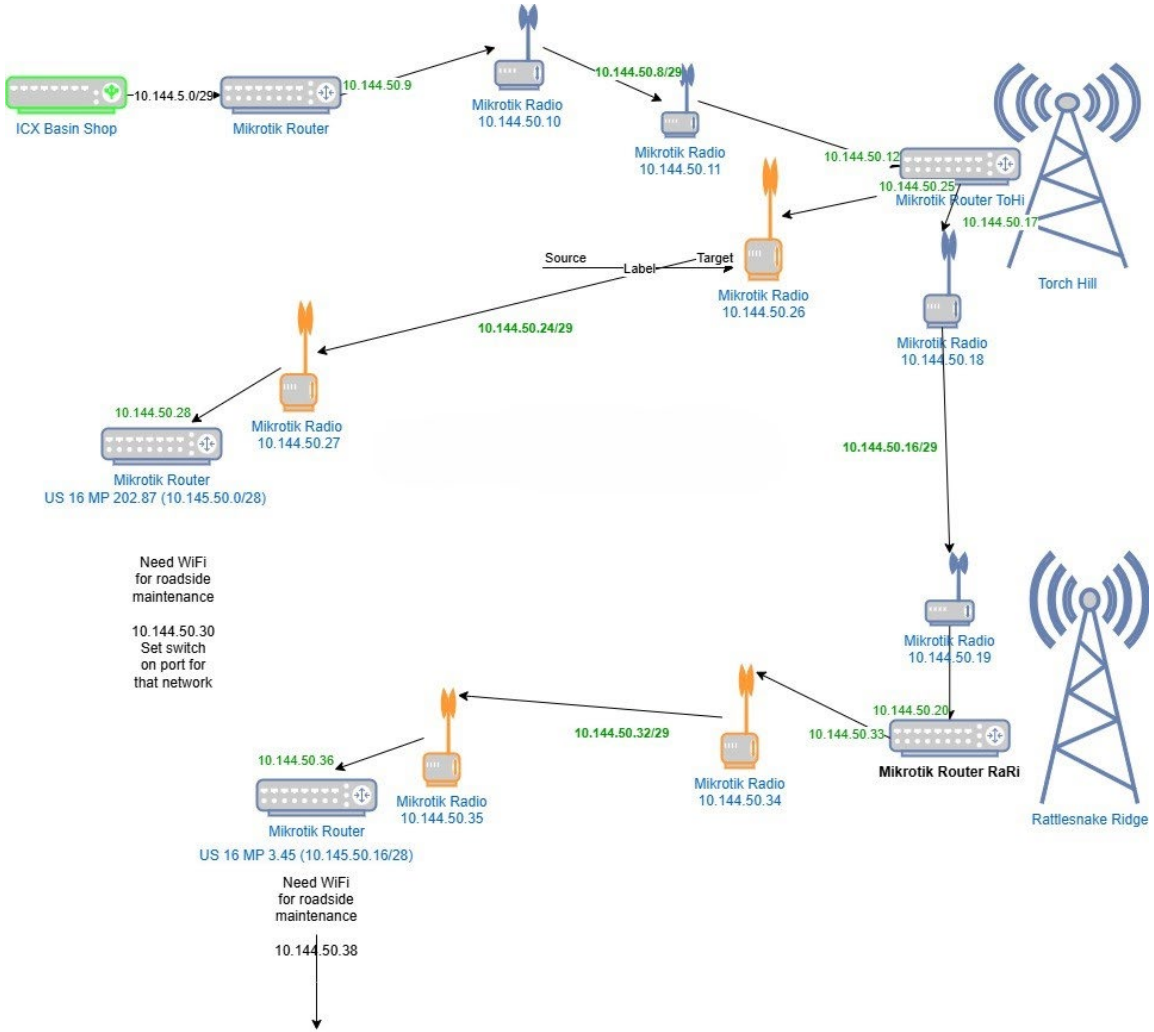
This area has several tower locations and has one at a WYDOT shop where we have Unified Network.



Initial Buildout

- Access to Unified Network was key for build.
- Towers were leveraged to connect multiple roadside sites in a 200 square mile area
- Redundancy was planned and available for future network expansion.
- Licensed 4.9 PTP links were installed for connections.

Basin Network Diagram



Lessons Learned

- Integrating OSPF with Unified Network
- Detailed Network Addressing
- Firewall Rules Can Kill You
- Utilizing Tools of Of your Equipment Will Save You

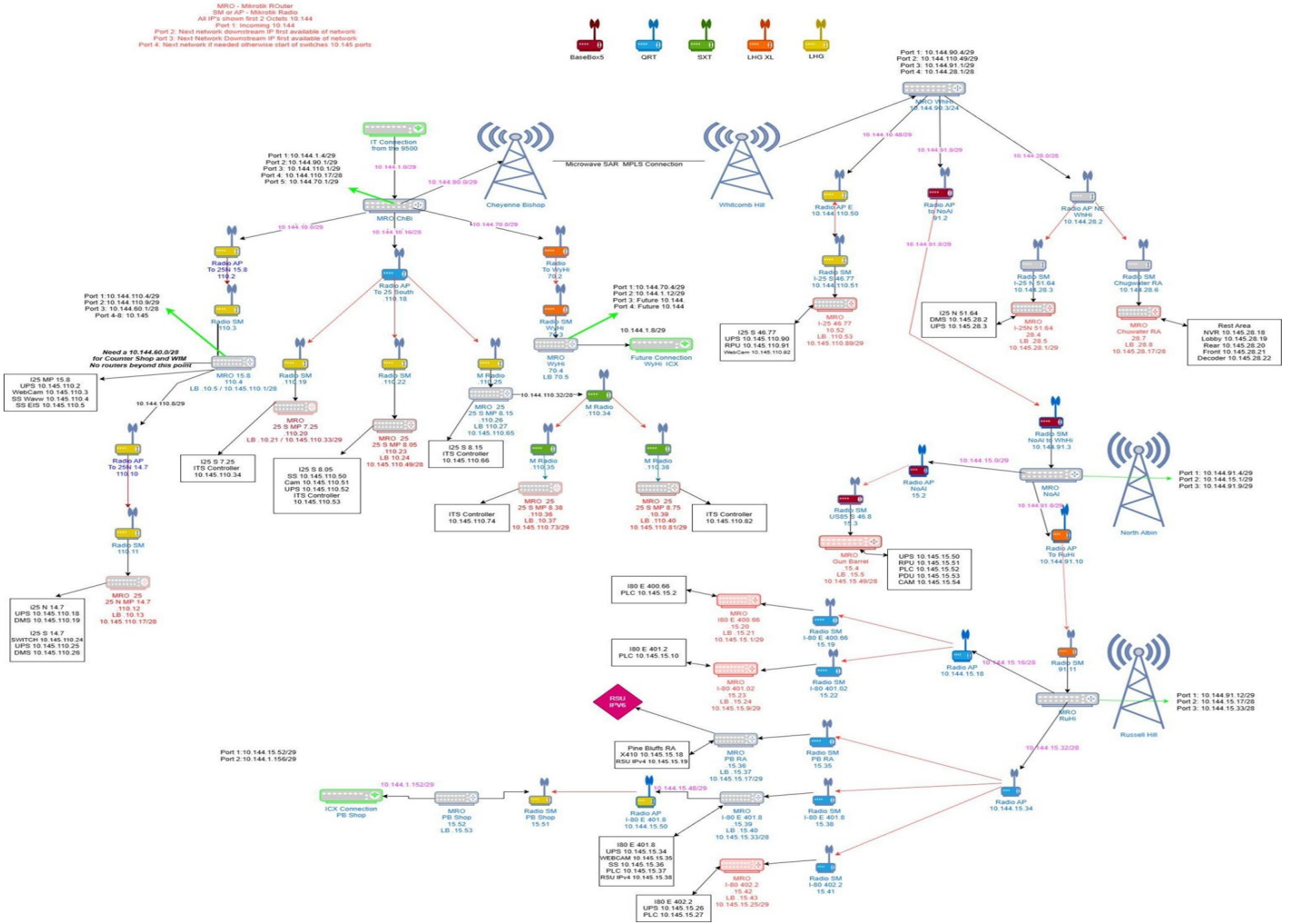
Future Expansion

Another key factor in selecting the Basin area for our first project was the Basin network is connected into several other MW towers. When WYDOT completes the MW upgrades we will build redundancy into our system utilizing adjacent towers and connections.

Proof of Concept 2

Russell Hill Project

Russell Hill was intended to be the first deployment of the new network design.
With several network drop off locations for redundancy, ability to utilize the SAR/ “E-Pipe” and proximity to headquarters it was an excellent test bed.


MRO - Mikrotik ROuter
SM or AP - Mikrotik Radio
All IP's shown first 2 Octets 10.144
Port 1: Incoming 10.144
Port 2: Next network downstream IP first available of network
Port 3: Next Network Downstream IP first available of network
Port 4: Next network if needed otherwise start of switches 10.145 ports
BaseBox5
QRT
SXT
LHG XL
LHG
Microwave SAR MPLS Connection
Cheyenne Bishop
Whitcomb Hill
North Albin
Russell Hill
Pine Bluffs RA
X410 10.145.15.18
RSU IPv4 10.145.15.19
RSU IPv6
Rest Area
NVR 10.145.28.18
Lobby 10.145.28.19
Rear 10.145.28.20
Front 10.145.28.21
Decoder 10.145.28.22
Need a 10.144.60.0/29 for Counter Shop and WIM
No routers beyond this point

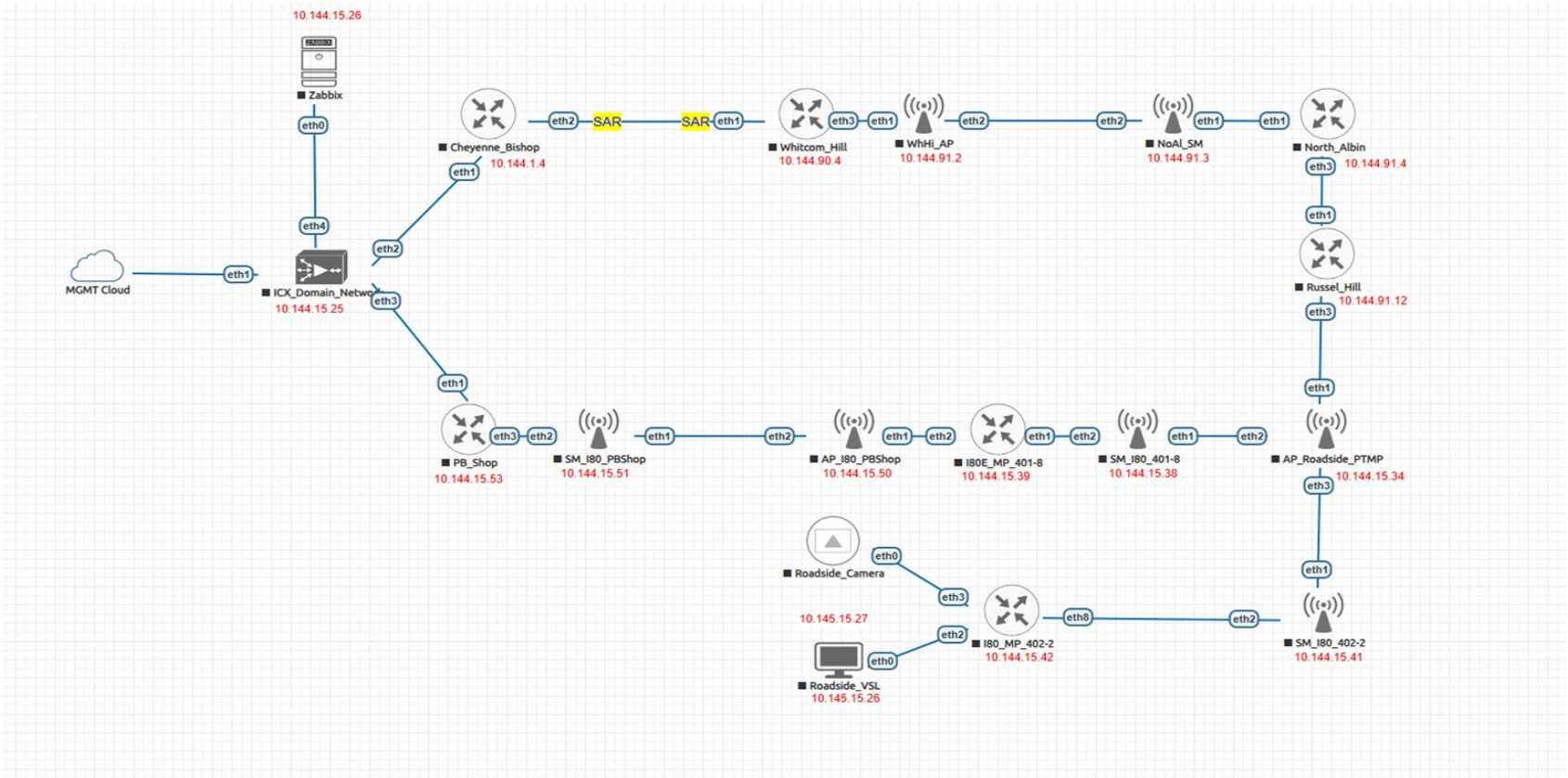
Lessons Learned

- Mikrotik’s Proprietary Discovery Protocol
- Romon is your friend
- Logistics Multiple ETS Unified Connections
- Integrating with ETS and OSPF

Project Success

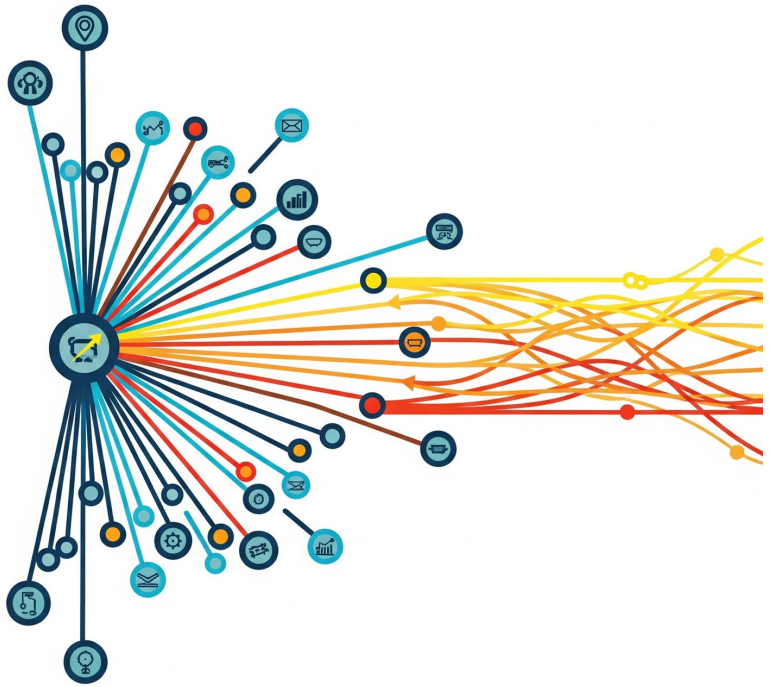
- We were able to successfully unload traffic at each network connection when a link was lost.
- OSPF worked as it should when a link became slow or incapacitated.
- Zero outages to roadside equipment on the system since deployment

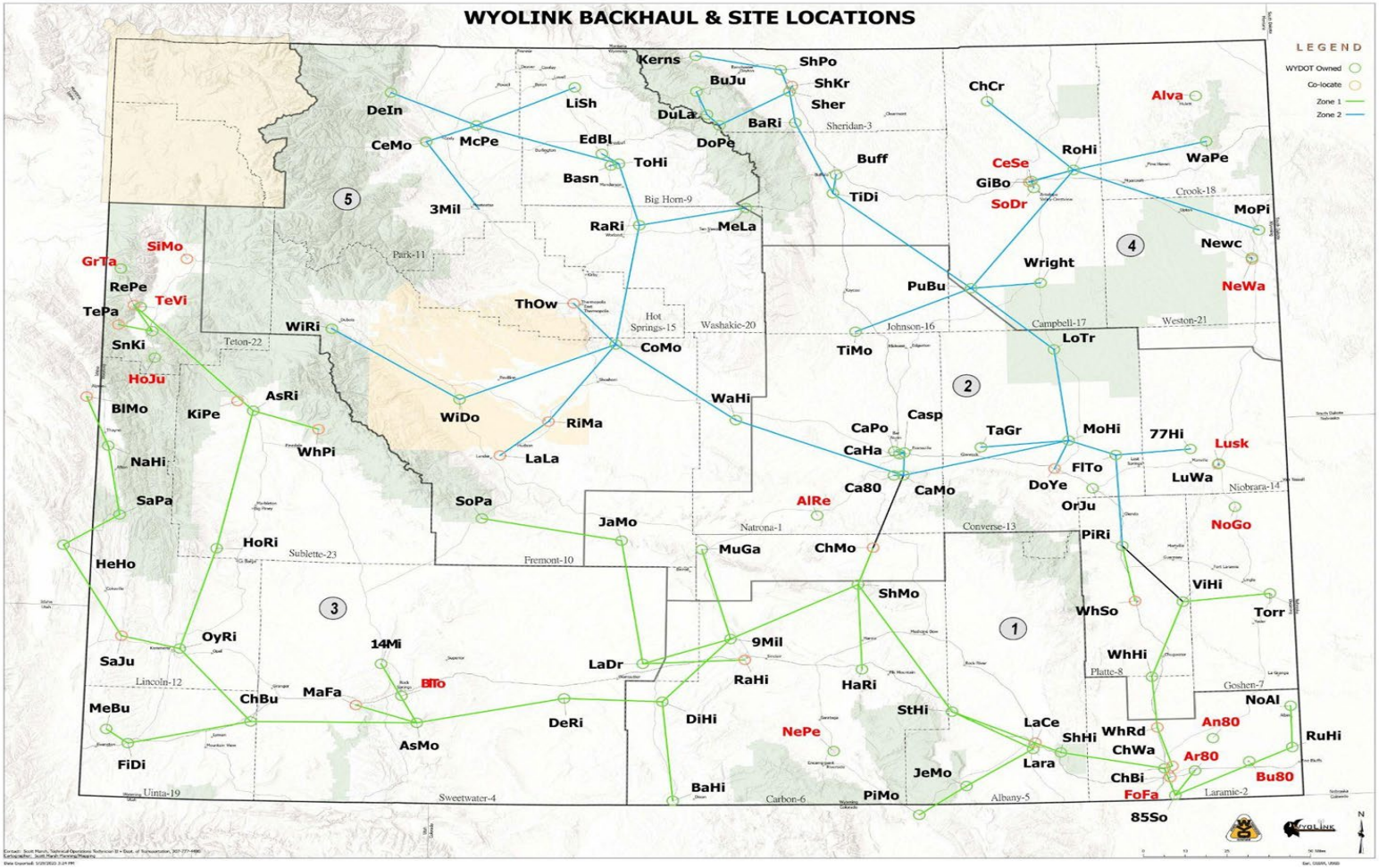
EVE OSPF Example Network



Next Steps

- Overhauling all remaining networks and com paths.
- Expanding network reach to new areas.
- Integrating more devices and technologies into the system.
- Planning for increased bandwidth and capacity needs.
- Enhancing redundancy for future system stability.




WYOLINK BACKHAUL & SITE LOCATIONS
LEGEND
WYDOT Owned
Co-locate
Zone 1
Zone 2
Kerns
ShPo
BuJu
ShKr
Sher
ChCr
Alva
DeIn
LiSh
DuLa
BaRi
Sheridan-3
CeMo
McPe
EdBl
DoPe
RoHi
WaPe
ToHi
Buff
CeSe
GiBo
SoDr
Basn
Big Horn-9
TiDi
Crook-18
MoPi
5
3Mil
RaRi
MeLa
4
Newc
SiMo
GrTa
Park-11
Wright
RePe
PuBu
NeWa
TeVi
TePa
ThOw
Hot Springs-15
Washakie-20
Johnson-16
Campbell-17
Weston-21
WiRi
Teton-22
CoMo
TiMo
LoTr
SnKi
HoJu
2
AsRi
WaHi
BlMo
KiPe
WiDo
RiMa
CaPo
Casp
TaGr
MoHi
77Hi
Lusk
CaHa
NaHi
WhPi
LaLa
FlTo
LuWa
Ca80
CaMo
DoYe
Niobrara-14
SaPa
SoPa
AlRe
OrJu
JaMo
Natrona-1
Converse-13
NoGo
HoRi
MuGa
ChMo
PiRi
Sublette-23
Fremont-10
HeHo
ShMo
ViHi
3
1
WhSo
Torr
OyRi
14Mi
9Mil
SaJu
LaDr
RaHi
HaRi
WhHi
Platte-8
Lincoln-12
BfTo
MaFa
Goshen-7
NoAl
ChBu
StHi
MeBu
DeRi
DiHi
LaCe
An80
RuHi
NePe
ShHi
WhRd
AsMo
ChWa
Ar80
FiDi
Lara
JeMo
ChBi
Bu80
BaHi
FoFa
Uinta-19
Sweetwater-4
Carbon-6
PiMo
Albany-5
Laramie-2
85So


In closing

Wyoming's ITS Network Revolution

- Cost effective equipment
- Network security and isolation
- Redundancy added
- Monitoring tools
- Team Effort
- Planning for the future

What are your Questions for us?