Providing Traveler Information in Rural Areas using Ad hoc Wireless Routing

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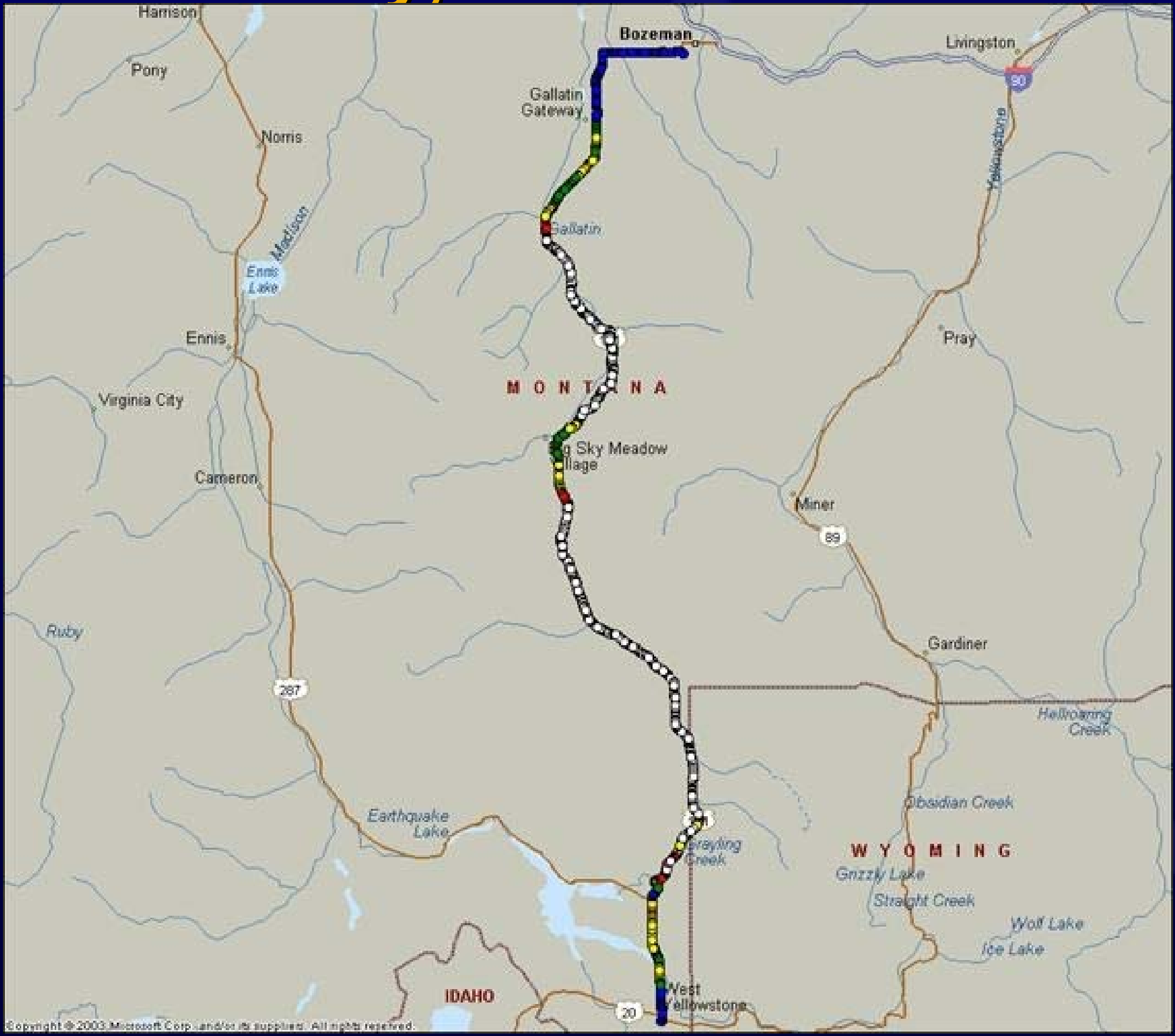
Outline

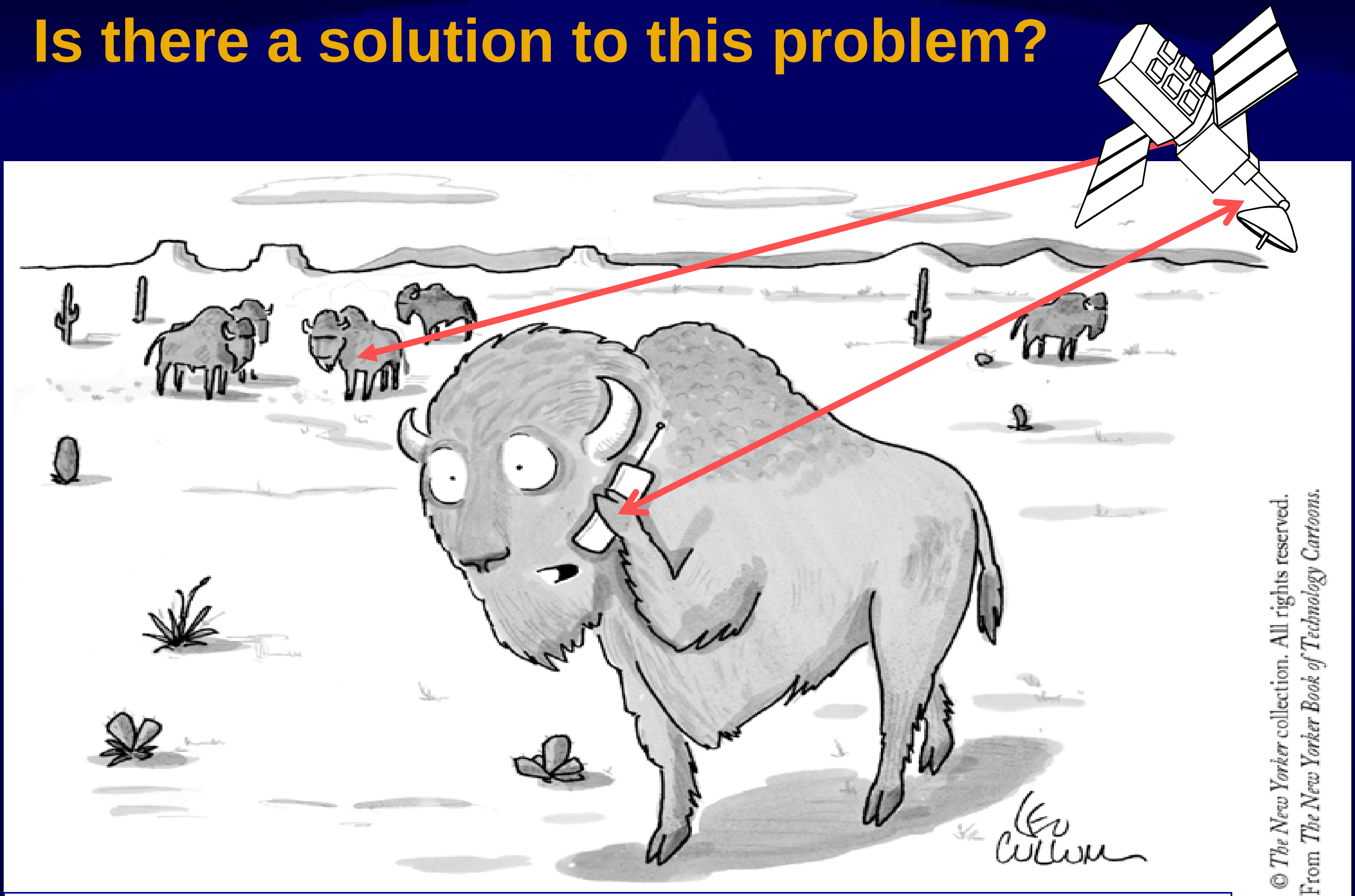
- Wireless coverage in rural areas
- Ad hoc networks
- Performance of conventional and new approaches
- Inclusion of terrain effects
- A practical example
- Conclusions

Cell phone coverage on Highway 191, Gallatin County, Montana



Data from WTI

Is there a solution to this problem?

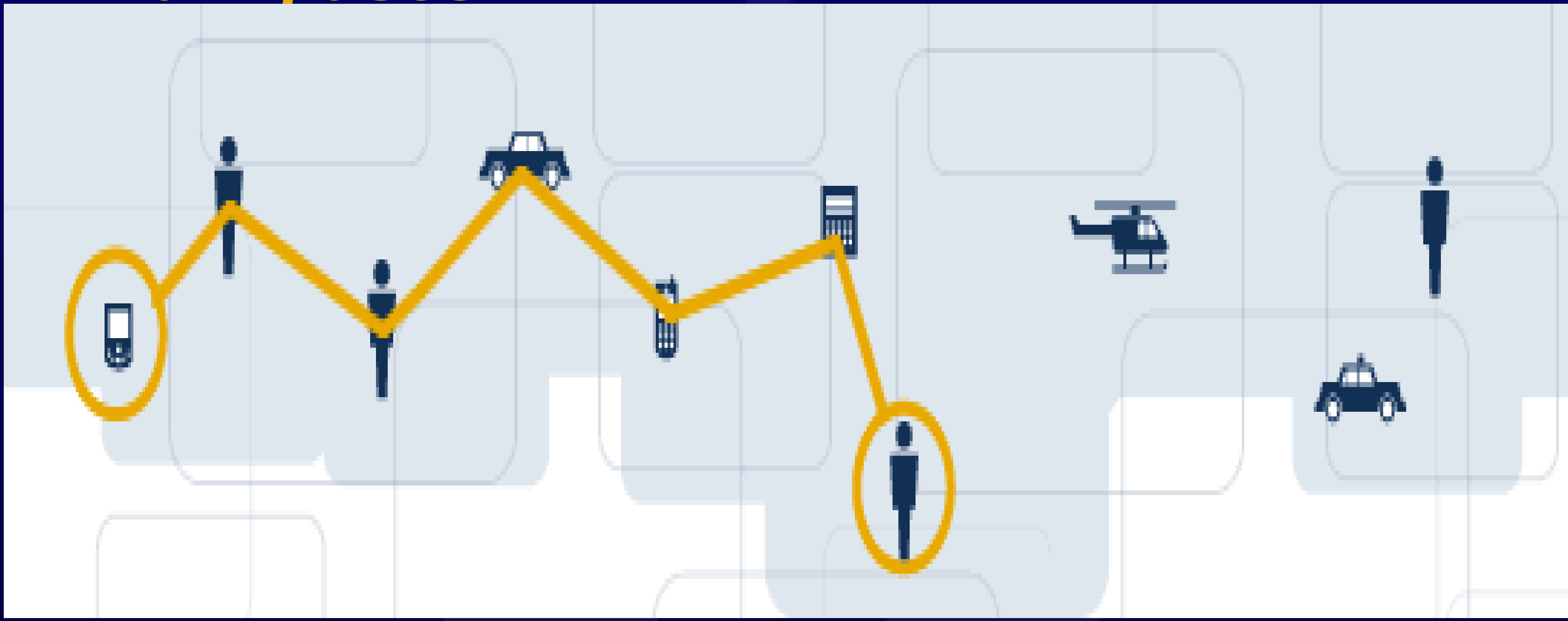


I Love the convenience, but the roaming charges are killing me!

Do we really need a network?

- Is this a dumb question……
- MAYBE NOT
- Let the users be the network!!!
- Multi-hop routing for very sparse areas

Ad hoc networking concept: already finding uses



- Military applications
- Public safety network trials
- Standards-based and proprietary solutions available

Ad hoc networking: classical assumptions

- Line of sight paths between nodes
- Existence of multiple links between nodes
- Link persistence and error-free performance
- Terrain is uniform or irrelevant
- Always a path from source to destination
- Node density high enough to assure communications at application level

Characteristics of the rural domain

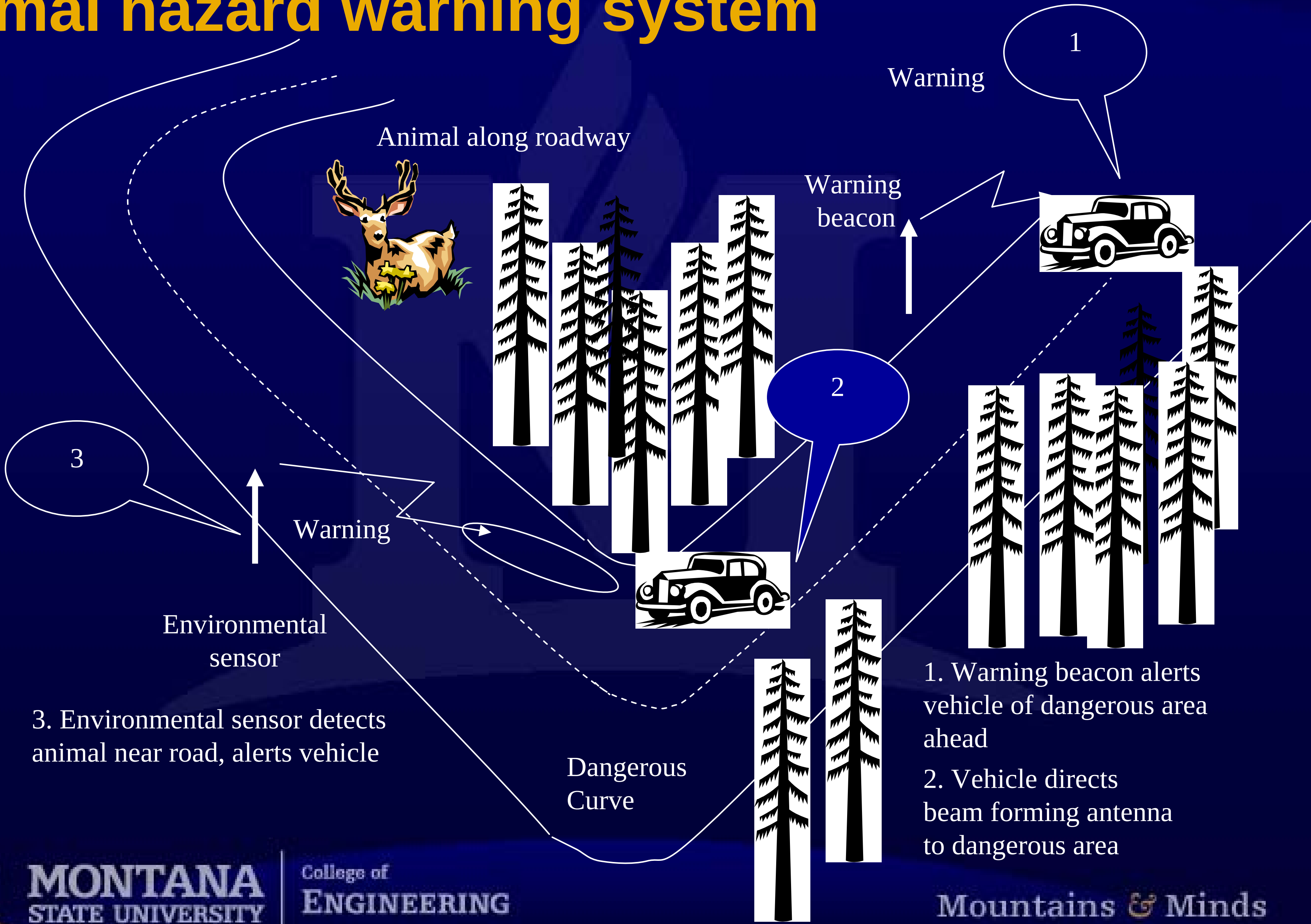
- Node density is low
- Connectivity is intermittent
- Source-destination paths not persistent
- Terrain may be a factor
- Error rates can be significant

Will ad hoc networking apply in this domain?

Rural traveler Information system

- Vehicular ad hoc network
  - No conventional wireless communication infrastructure
  - MAC layer based on 802.11 standards or similar
- Applicable to low node density, sparse rural area
- What's the appropriate routing protocol?

Ad hoc network application: improved animal hazard warning system

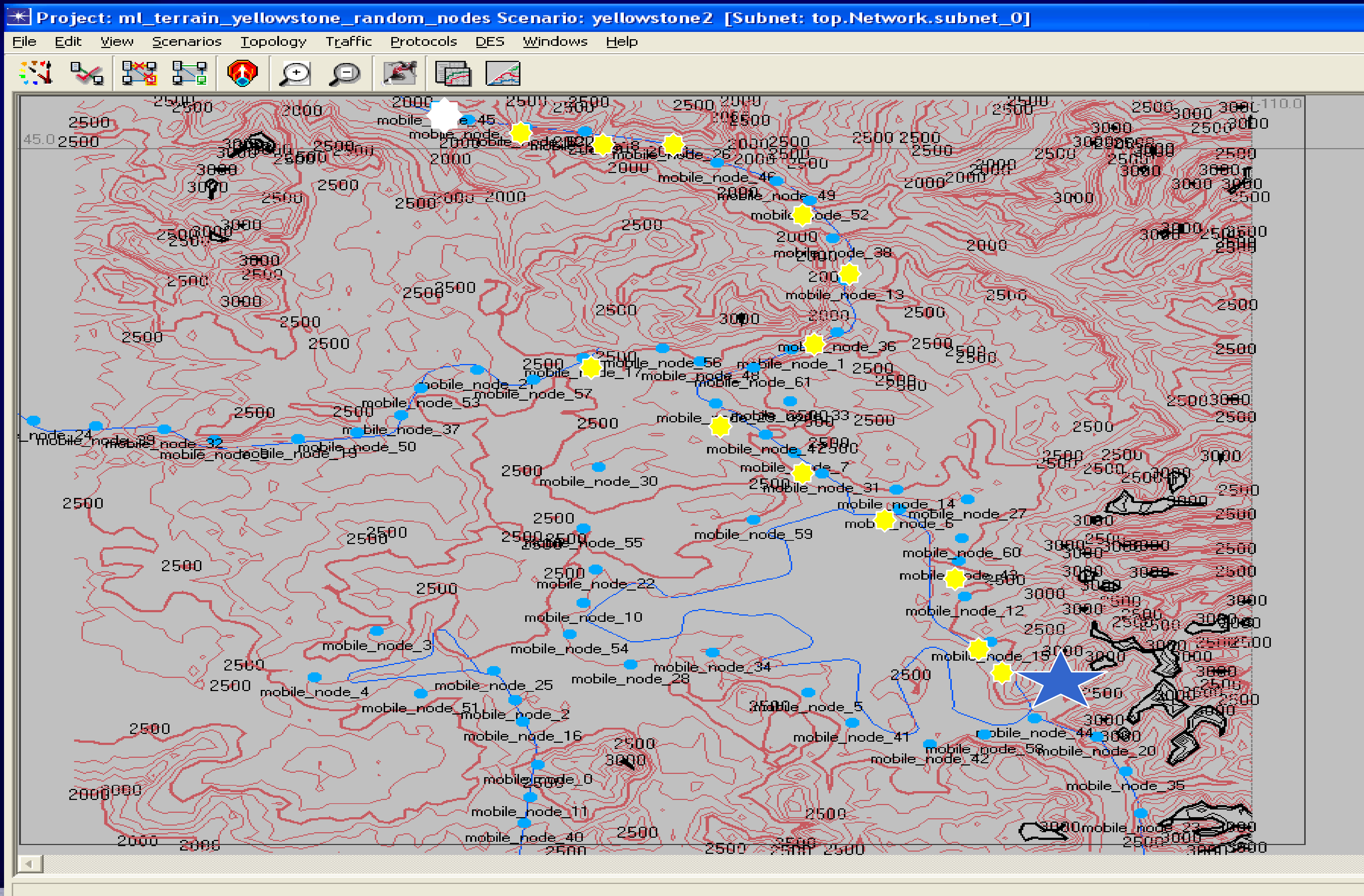


3. Environmental sensor detects animal near road, alerts vehicle

1. Warning beacon alerts vehicle of dangerous area ahead

2. Vehicle directs beam forming antenna to dangerous area

Mobile nodes (100 in this figure)and their trajectories



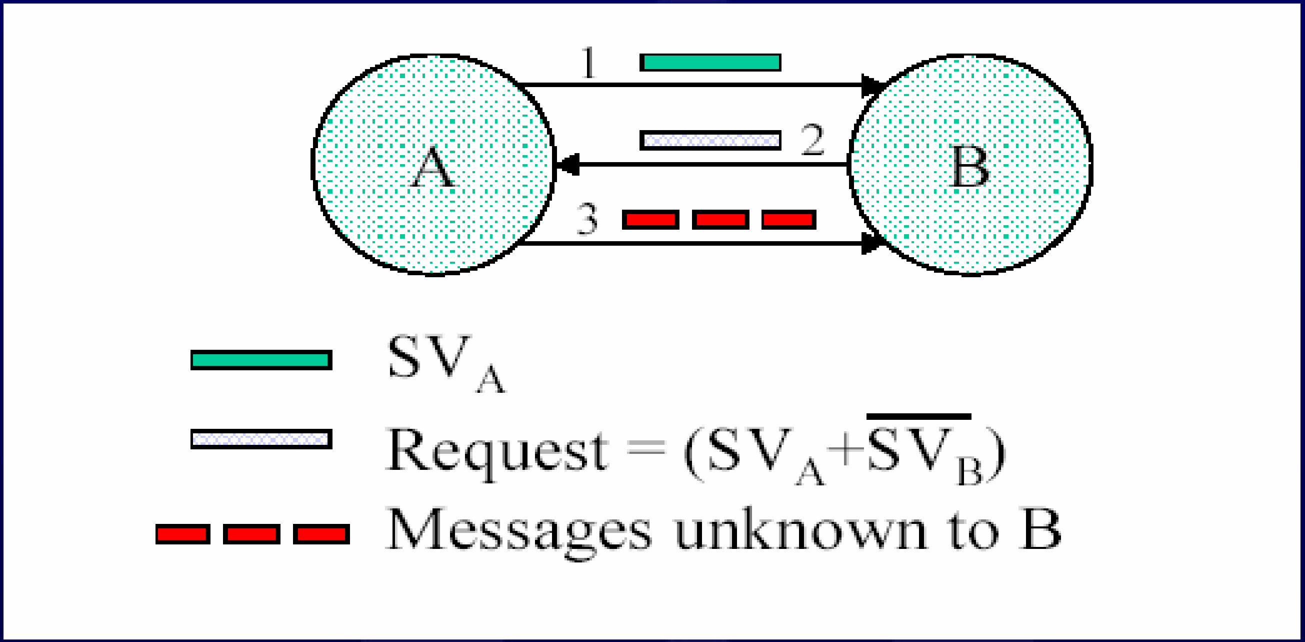
Simulation results using a conventional routing protocol

Route discovery time at different radio ranges when Nv=2800

Radio range (meters)	Percentage of simulations where route found	Minimum route discovery time (seconds)
100	0%	No route found
200	0%	No route found
300	72.8%	0.28
400	81.9%	0.20
500	100%	0.16

Protocol: DSR (dynamic source routing)

Epidemic routing: store and forward



- No assumption of the connectivity of the underlying network
- Messages exchanged when two nodes come into the transmission range of one another

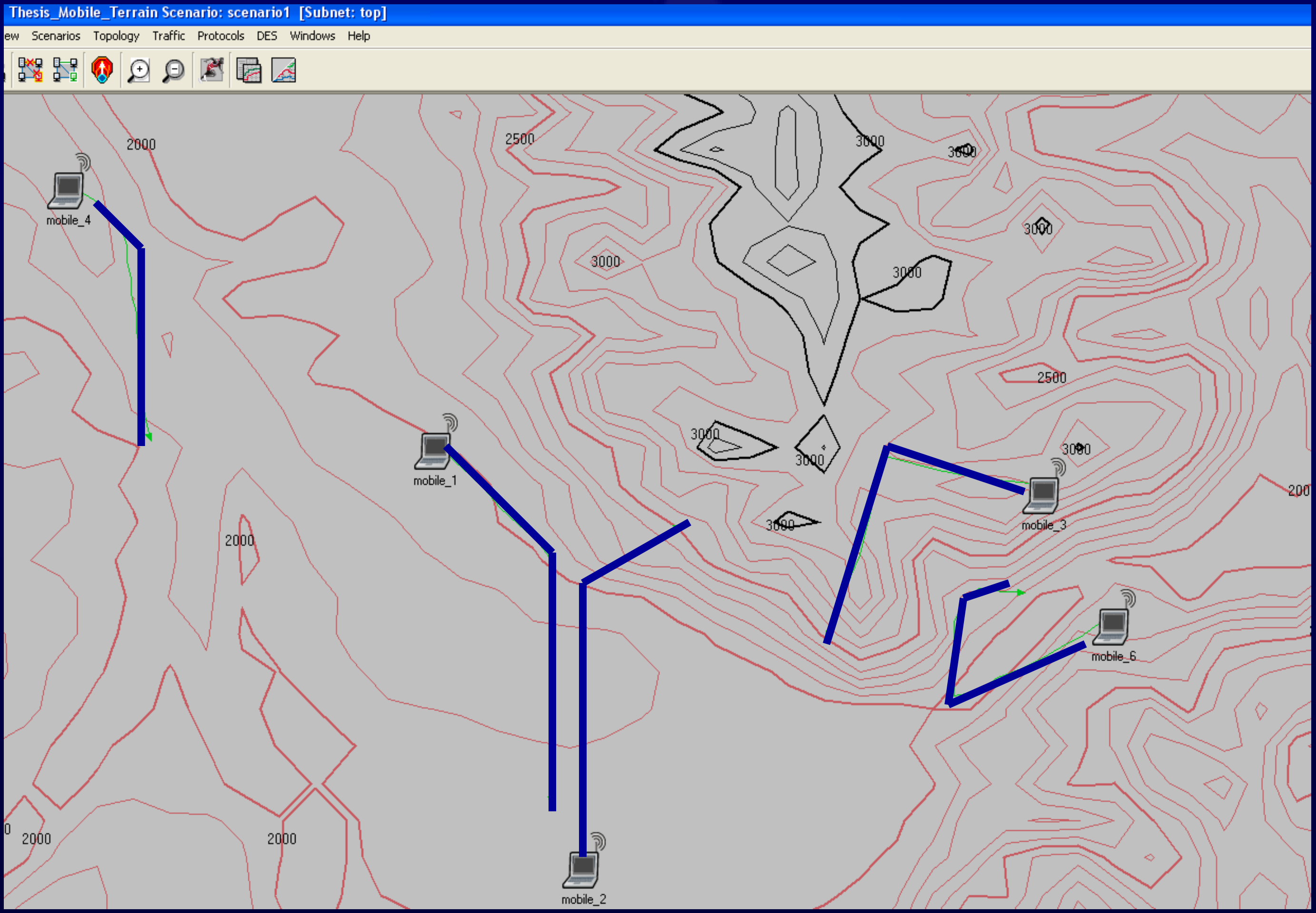
Calculations– similar to epidemic routing

Number of vehicle Nv = 1400

Radio range (R) (meters)	Transit time (T) (minutes)
100	84
200	84
300	58
>=400	0

Results show promise for epidemic routing

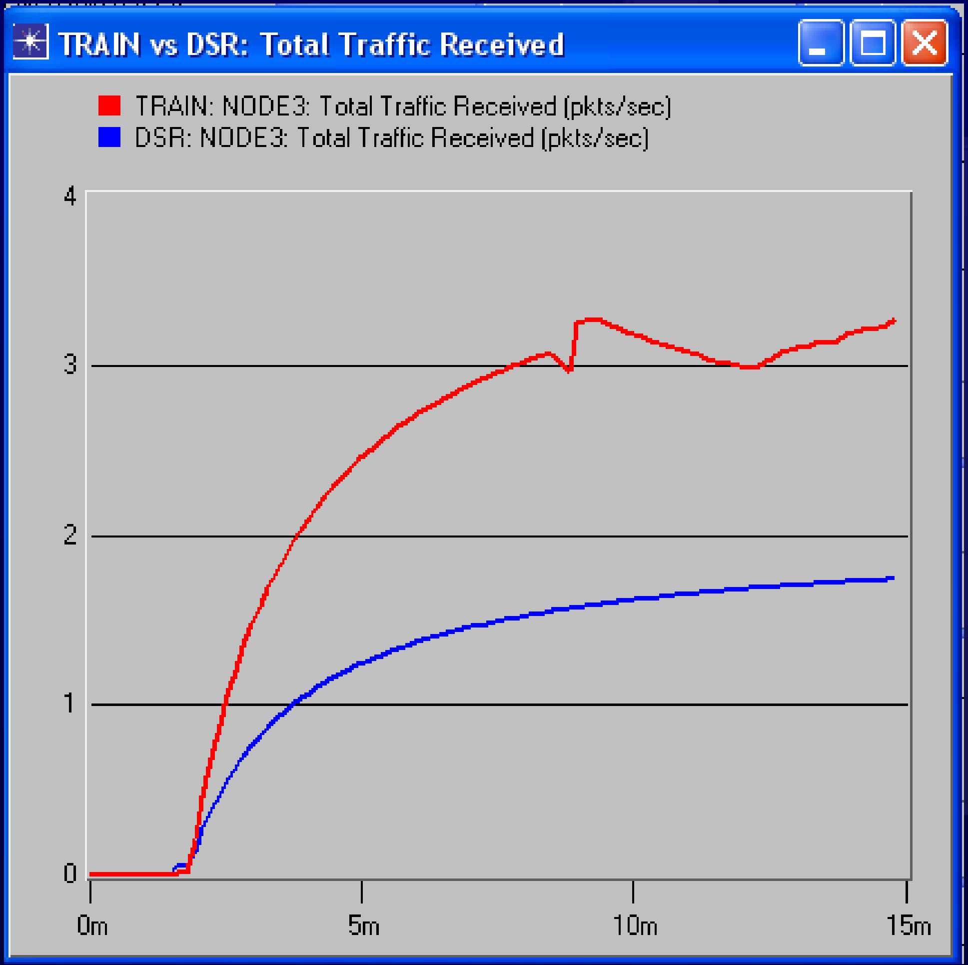
What about terrain?



Terrain, location and trajectory information are used to determine the location of other node at any time and then determine path loss and blocking

Path loss and blocking calculation

Some preliminary simulation results



Unmodified DSR

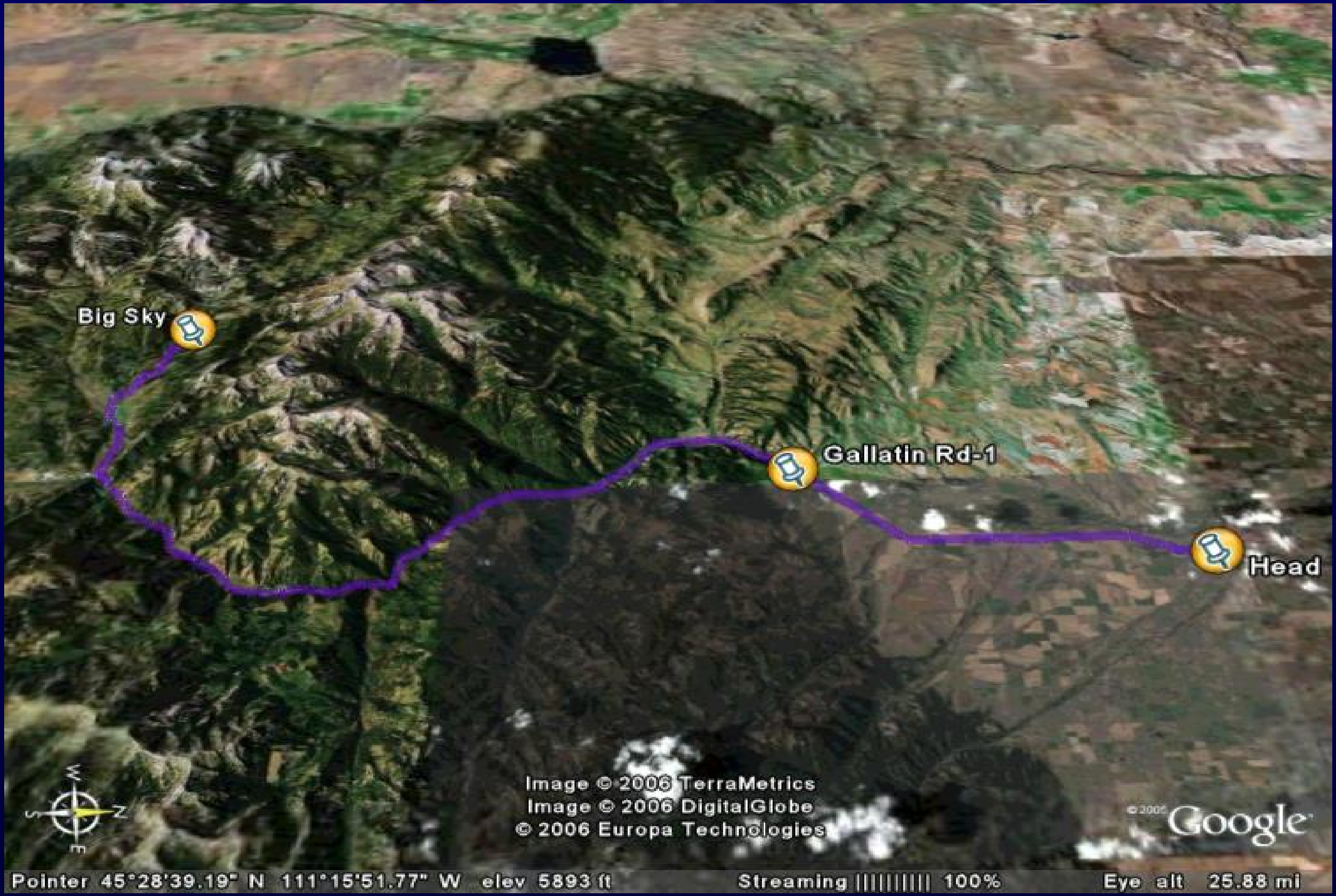
TRAIN (terrain-based)

Average traffic received TRAIN vs unmodified DSR

What happens in the real world?

- Consider a real world scenario and application
- Examine terrain and develop a coverage model
- Model connectivity using ad hoc routing
- Consider implementation with commercial equipment

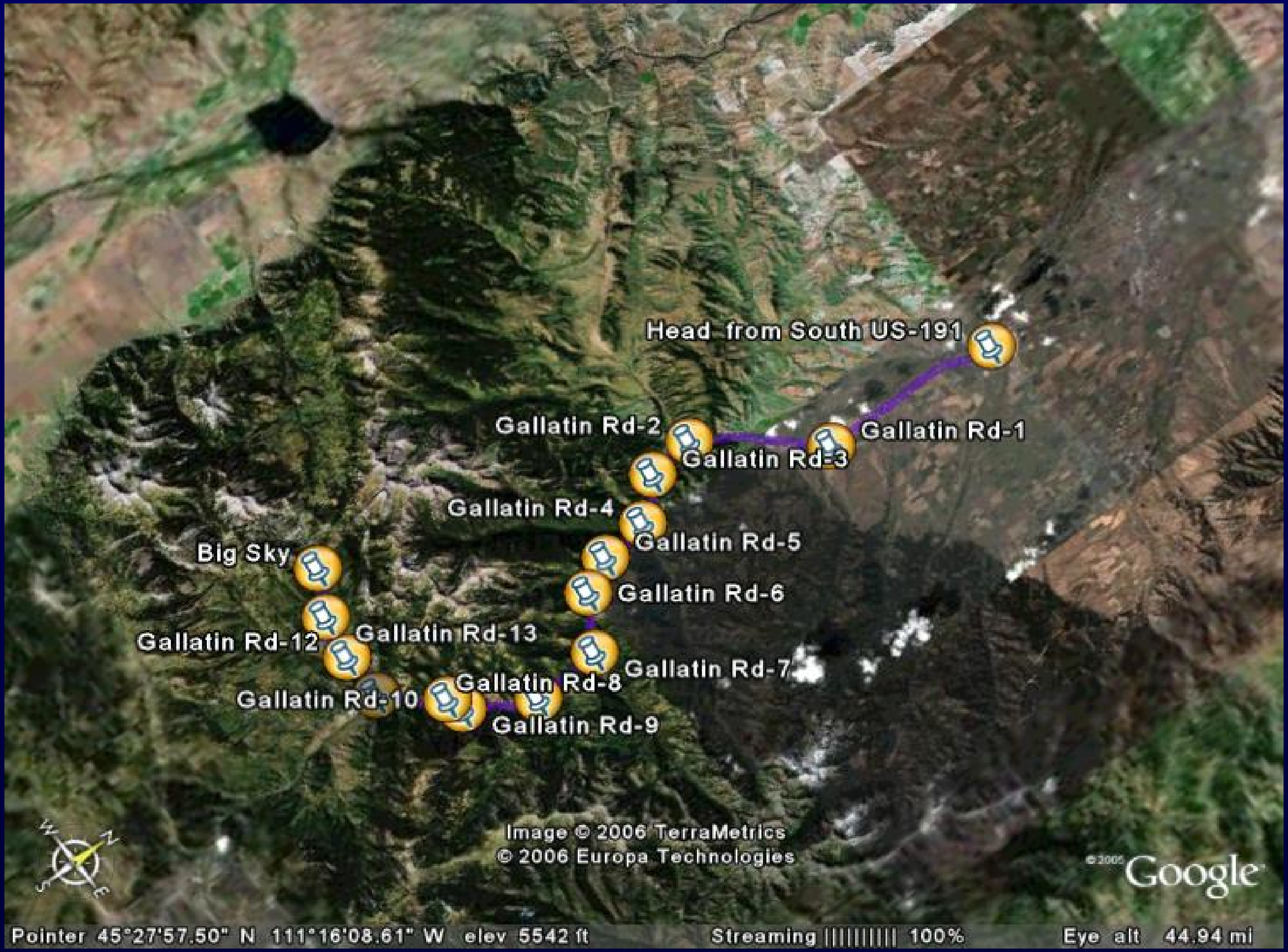
The highway 191 example



Multi-hop network for highway 191

- Use vehicle to roadside communications
- Form a multi-hop chain of roadside repeaters
- Use 900Mhz spectrum
  - Unlicensed
  - Longer range than Wi-Fi (2.4 GHz)

Highway 191: 15 repeater network



Network characteristics

- Repeater spacing: 0.7 to 5 miles (terrain dependent)
- Throughput: up to 160kb/sec
- Power consumption: 15 watts per node (max), solar/battery powering is feasible
- Technology: commercially available
- Applications: IP-based data

Conclusions

- Connectivity in rural areas using ad hoc network techniques is feasible
- Routing protocols that work in sparse conditions are needed
- Terrain effects must be taken into account
- Commercial products are becoming available

Acknowledgements

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