Validation of a CRV Model Using TVWS Measurements

Khalil Anderson[1], Lauren Lusk[2], Marti Hands[3], Garrett Vanhoy[4], Tamal Bose[4]

[1] University of Maryland, Baltimore County, USA
[2] University of Oklahoma, USA
[3] Texas Tech University, USA
[4] University of Arizona, USA

THE UNIVERSITY OF ARIZONA

Agenda

- **Background**

- **Measurements**

- **Simulation**

- **Results/Conclusion**

Background

Vehicular Networks

- **There is substantial academic and commercial interest in getting a vehicle to drive itself.**

- **Many of the standard operations can be accomplished with sophisticated sensors and computer vision.**

- **Allowing several autonomous vehicles to communicate can enhance their capabilities and allow integration with non-autonomous vehicles.**

Vehicular Networks

- **802.11p is the proposed standard to manage connections between vehicles that is similar to Wi-Fi**

- **WAVE is an enhancement to 802.11p that allows low-latency communication between vehicles**

- **WAVE can accommodate some media applications, but it's not designed for it.**

Vehicular Networks

- **The spectrum allocated for WAVE and the protocol itself likely cannot handle high-density traffic with high demand for data.**

- **The viability of using TV White-Space for high-bandwidth applications in dense Vehicular Networks has not been well-studied**

WAVE

- **WAVE consists of the 5.9GHz band which has 75 MHz wide (5.850-5.925 GHz)**

- **Each channel is 10 MHz wide except for the 5 MHz guard band**

- **There are 2 safety channels, a control channel and 4 service channels**

TV White Space

- **US Government vacated the bands between 470 MHz and 890 MHz that had previously been used to transmit analog television**

- **One of the proposed uses of TVWS is the implementation of Wi-Fi across the bands, which has been dubbed White-Fi.**
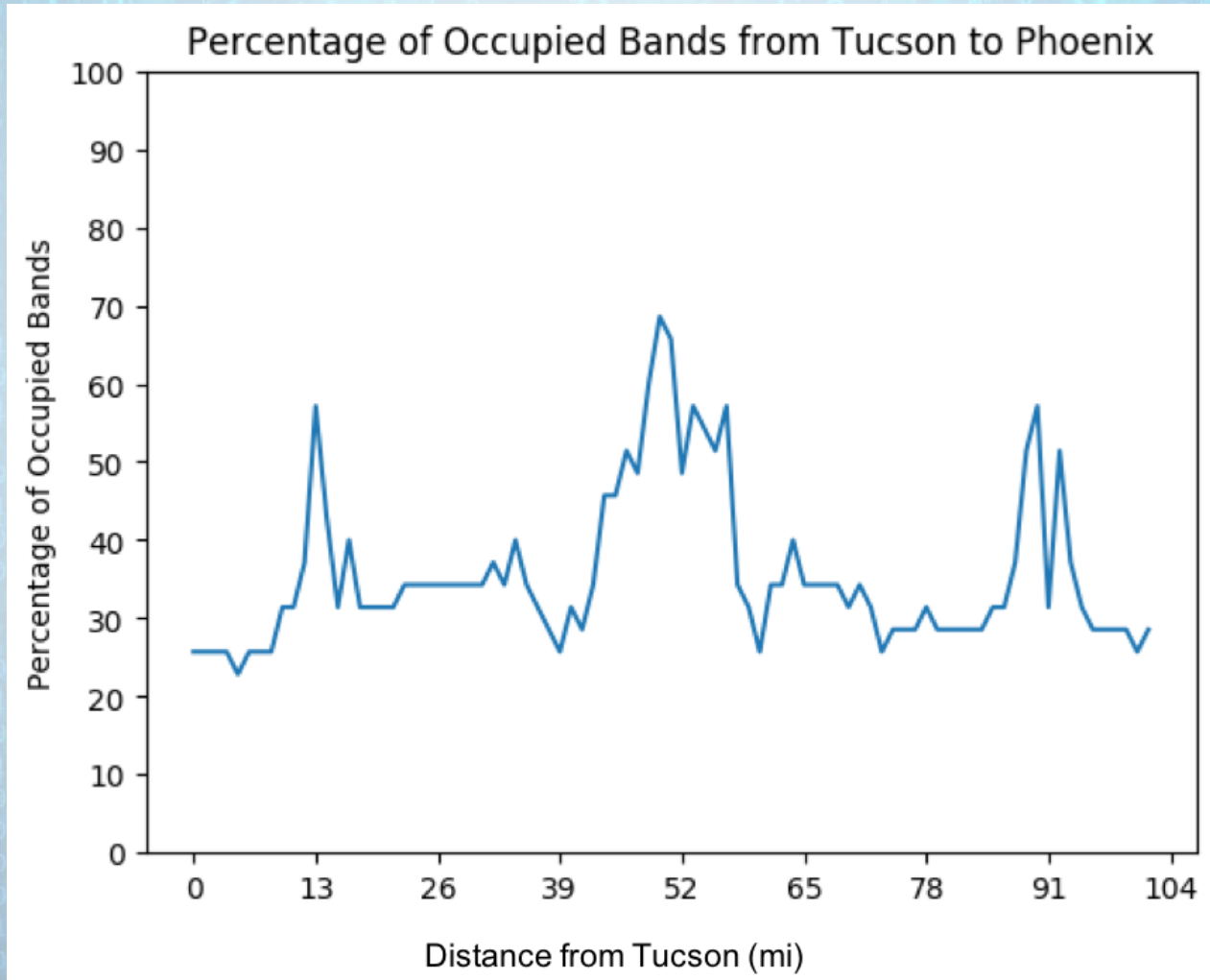
Measurements

Measurements

- **While many researchers have made spectrum measurements, unprocessed data has not been made easily available**

- **Because of this, new measurements were made of the channels between 680 MHz and 890 MHz**

- **The spectra was measured while in a moving vehicle using software-defined radio (SDR)**

Measurements

- **The hardware used includes a laptop, an Ettus N200, and a LTE Dipole antenna**

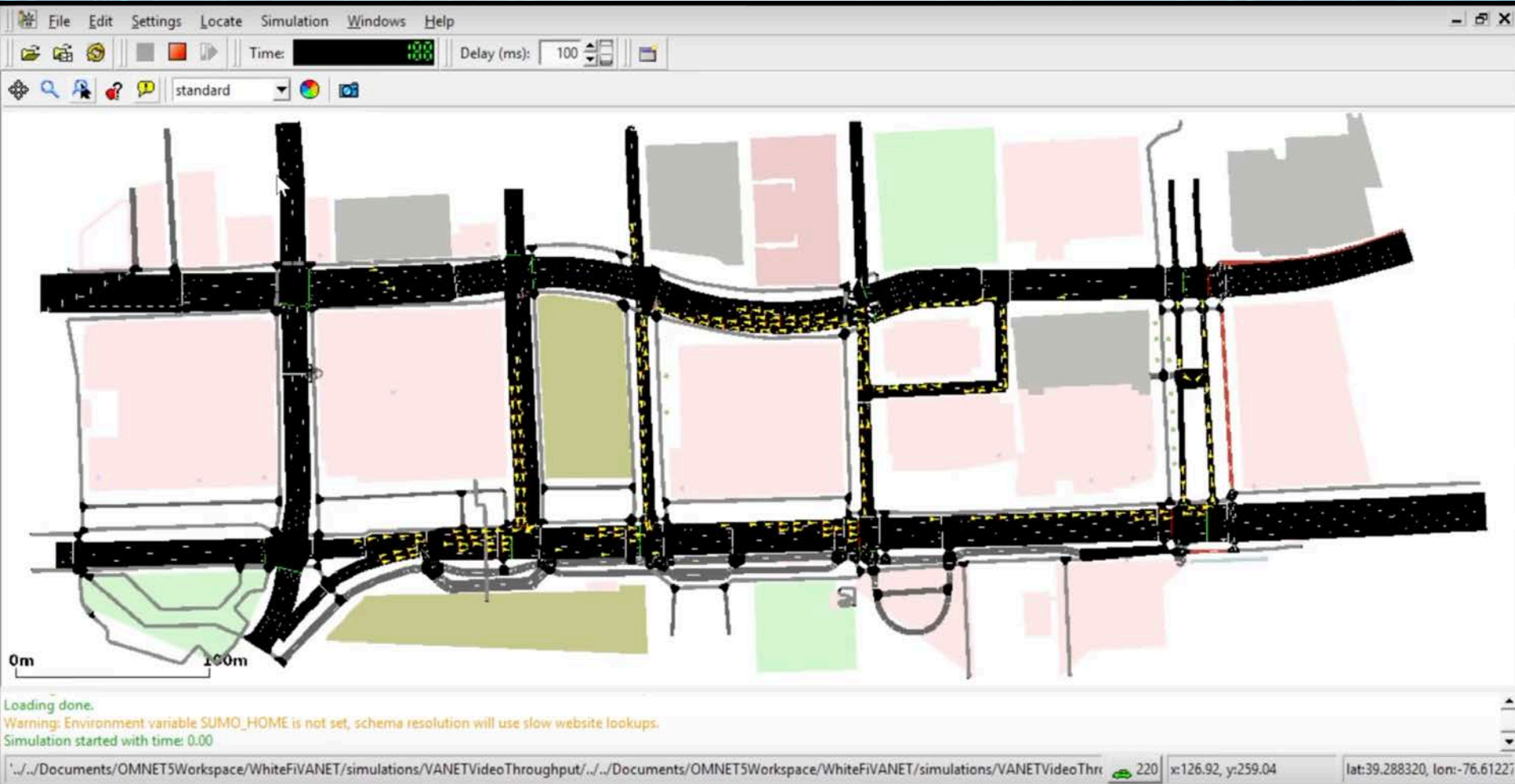- **Channels were sampled for 5 ms at a time, at a rate of 6 MHz**

Measurements

Percentage of Occupied Bands from Tucson to Phoenix

OMNet++ Simulations

Simulations

- **OMNet++ combined with Veins and INET framework**

- **Veins models the mobility for vehicles in the simulation**

- **INET allows for extra customization in the multiple levels of the OSI model along with a pre configure UDP Video Streaming application**
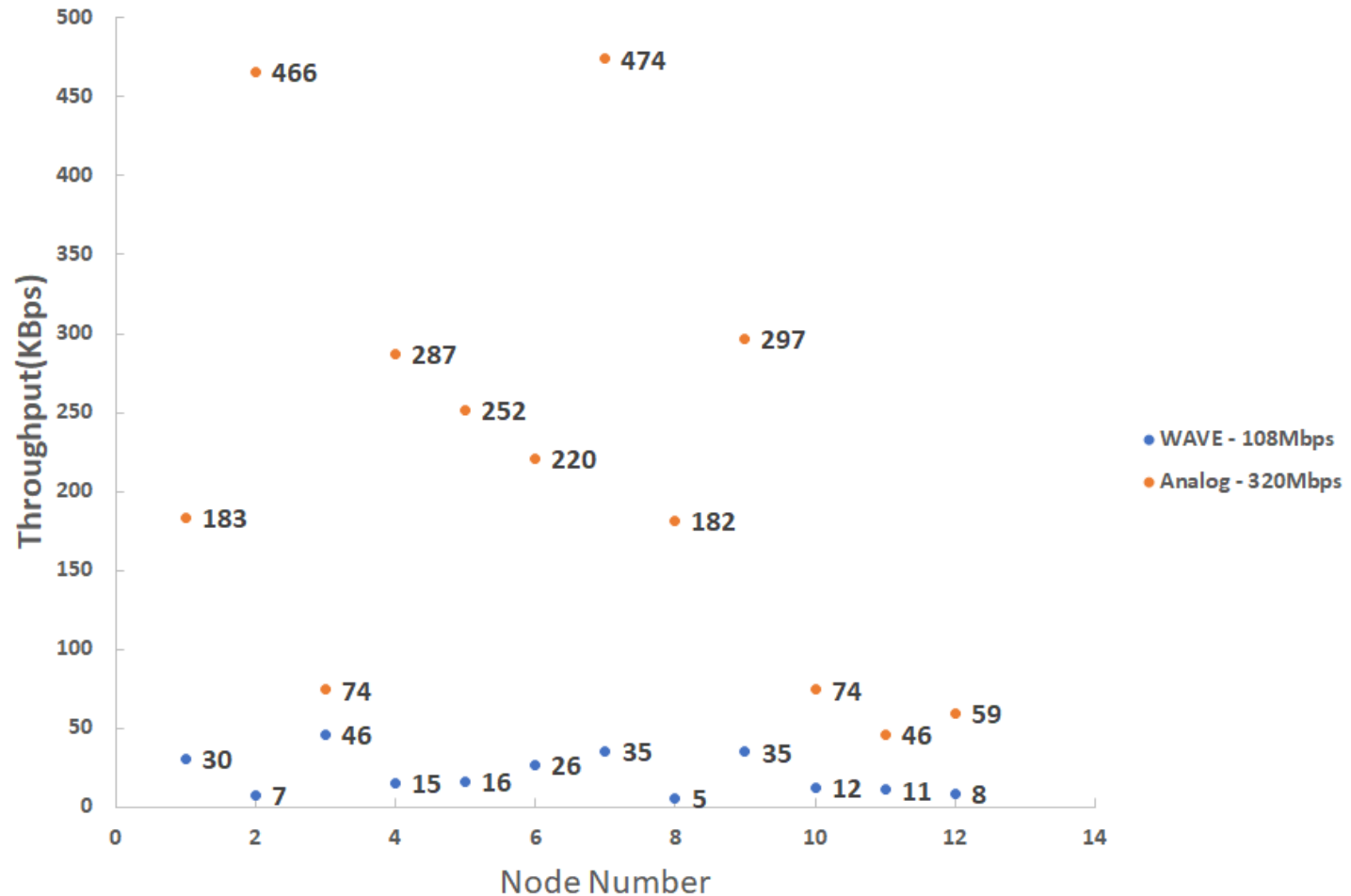
OMNet++ Simulation

Simulations

- **Traffic Generation**
  - **Attempting to stream a 2GB video with 2000B packets**
  - **Send interval for packets at 25 microseconds for analog and 100 microseconds for WAVE.**

- **Parameters**
  - **Basic carrier-avoidance MAC**
  - **Rayleigh fading models for channel**

- **"Analog" is standard Wi-Fi over the analog TV bands**

Simulations

- **Bit Rates:**
  - **"Analog": 80 Mbps, 160 Mbps, 240 Mbps, 320 Mbps**
  - **WAVE: 27 Mbps, 54 Mbps, 81 Mbps and 108 Mbps**

- **Multiple bit rates are used to mimic a road side unit simultaneously using multiple channels to transmit and receive which is why they are multiples of the lowest bit rate**

Simulations

Comparison of Nodal Bitrates between WAVE and Analog

Simulations

Run Type - Amount of Channels	Throughput(MBps)
WAVE - 1	1.512
WAVE - 2	2.816
WAVE - 3	3.900
WAVE - 4	4.348
Analog - 1	5.711
Analog - 2	7.315
Analog - 3	9.624
Analog - 4	11.463

Conclusion

Conclusion

- Given the accumulated data, TV white space has many "spectrum holes" especially on roads.

- The simulation also indicates that White-Fi has the potential to handle high-density traffic.

- The next step would be real-world tests to see how White-Fi works in a vehicular network