



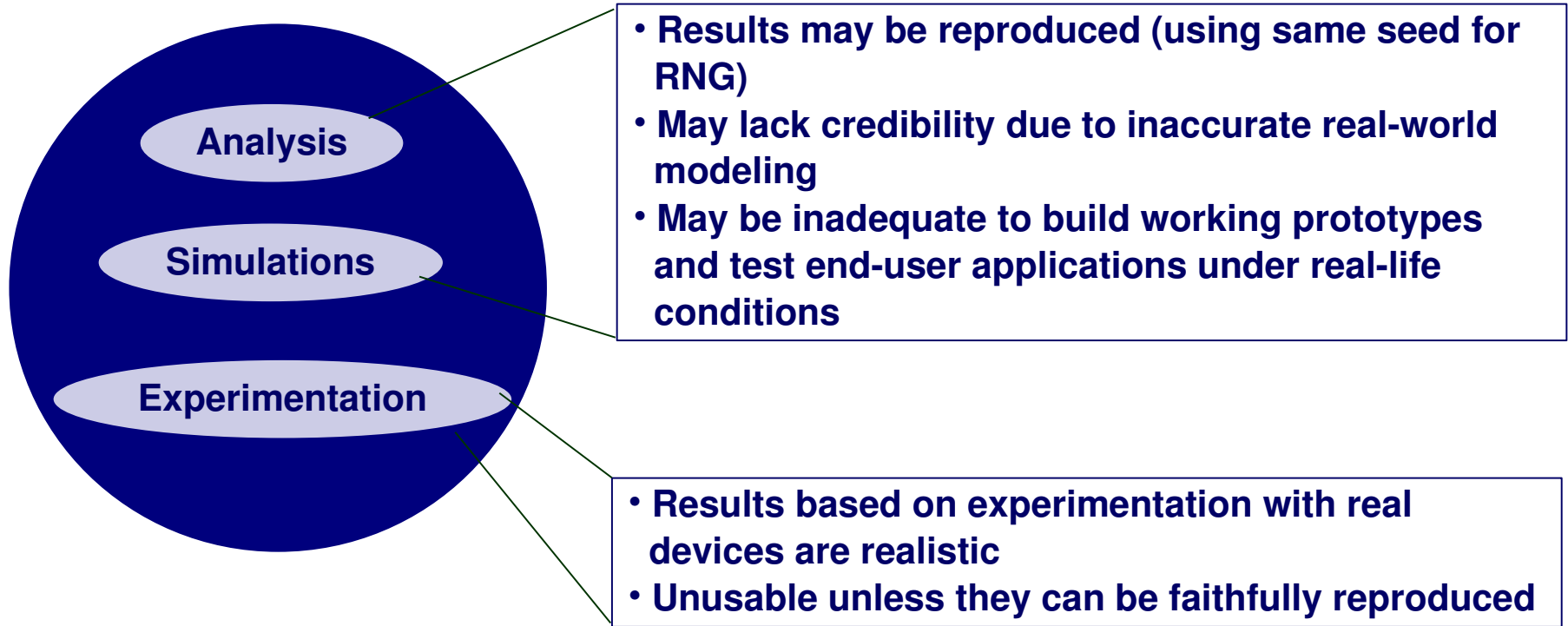
Addressing Repeatability In Wireless Experiments Using ORBIT Testbed

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Research on Wireless Networking: Current approaches



How to ensure that wireless experiments are repeatable???

Factors Affecting Repeatability

Hardware

- Differences in commercial hardware
- Difference tolerances and ageing for various low cost components

Software

- Software or firmware bugs that may manifest as inconsistent experimental results

Environment

- Uncontrolled interference over time and space
- Co-located infrastructure APs, opening and closing of doors, movement of people etc.

Some proposed solutions...

- Using RF cables instead of wireless links to reduce the effects of environment
- Using an emulator to emulate different channel behavior
- Anechoic chambers for RF Isolation

Some of the realistic wireless channel effects may be lost by using RF cables or emulators

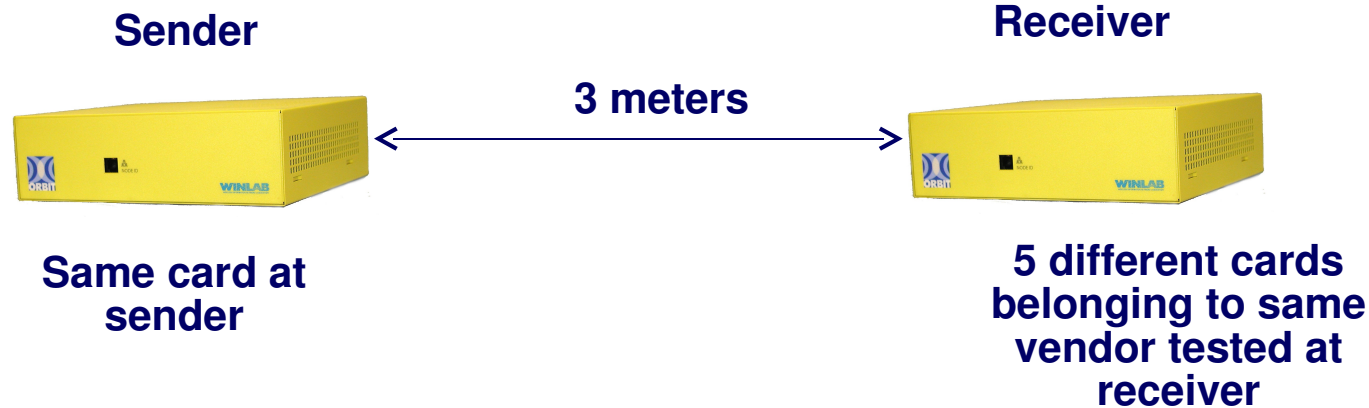
Anechoic chamber to guarantee RF isolation for 400 nodes is too expensive!!!!

Our approach

- Retain wireless links to support realistic wireless channels
- Measure and quantify hardware difference across multiple devices
- Propose an approach to address repeatability using periodic hardware calibration

Variation across different cards... An example

Experiment Setup



For every card at the receiver

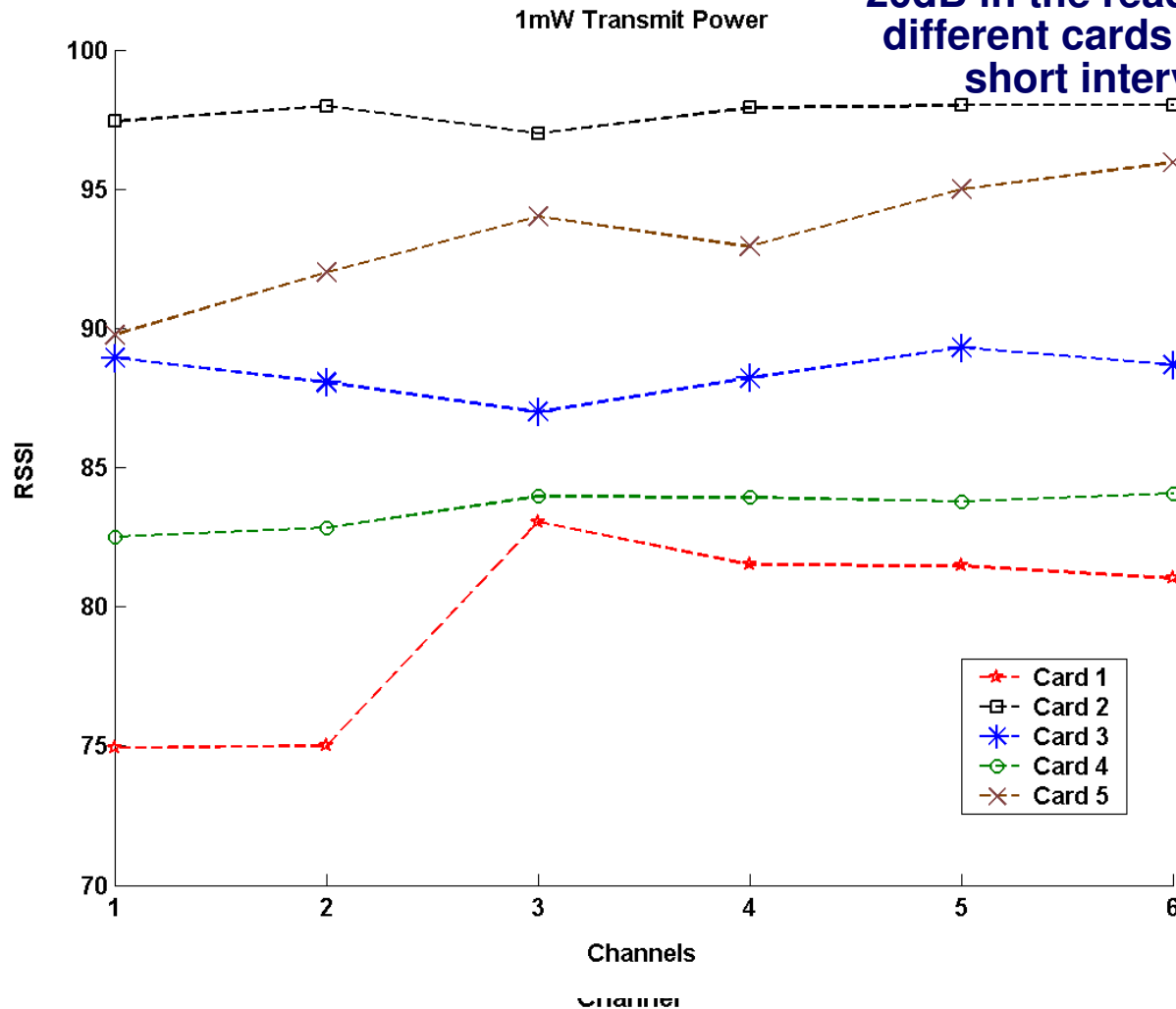
For transmit power levels of $x = 1$ mW, 5 mW and 20 mW

Sender at x mW offers constant offered load to receiver on channel 1 for 120 seconds

Receiver monitors RSSI for every packet

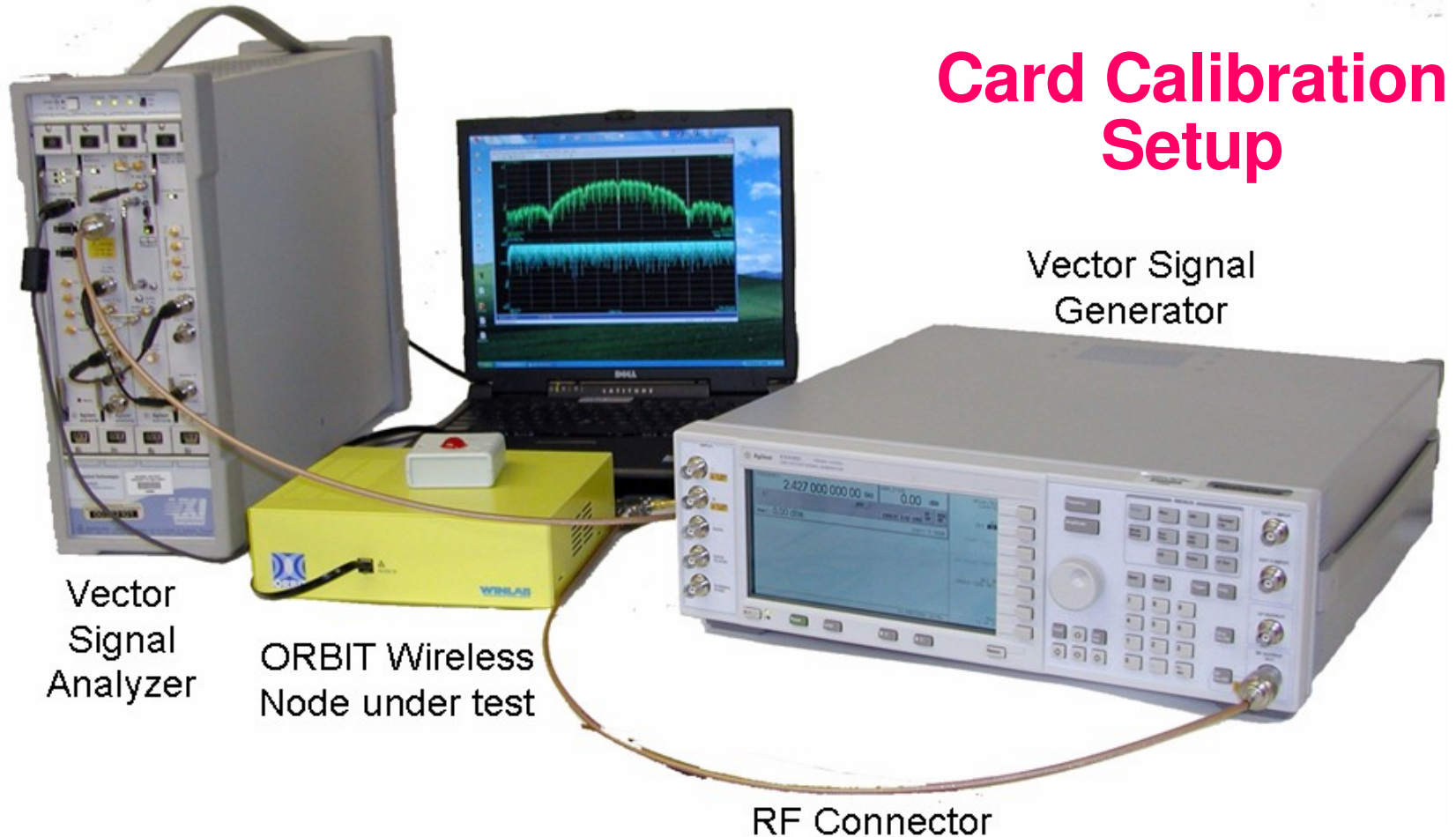
Variation of reported RSSI

Inherent discrepancy of nearly 20dB in the readings reported by different cards over a relatively short interval of time!!!



Our approach: Card Calibration

- Calibrate transmit and receive side of the cards
- Record corrections to be applied for each card based on the discrepancies observed



Card Calibration Setup

Vector Signal Generator

Vector Signal Analyzer

ORBIT Wireless Node under test

RF Connector

Transmitter calibration

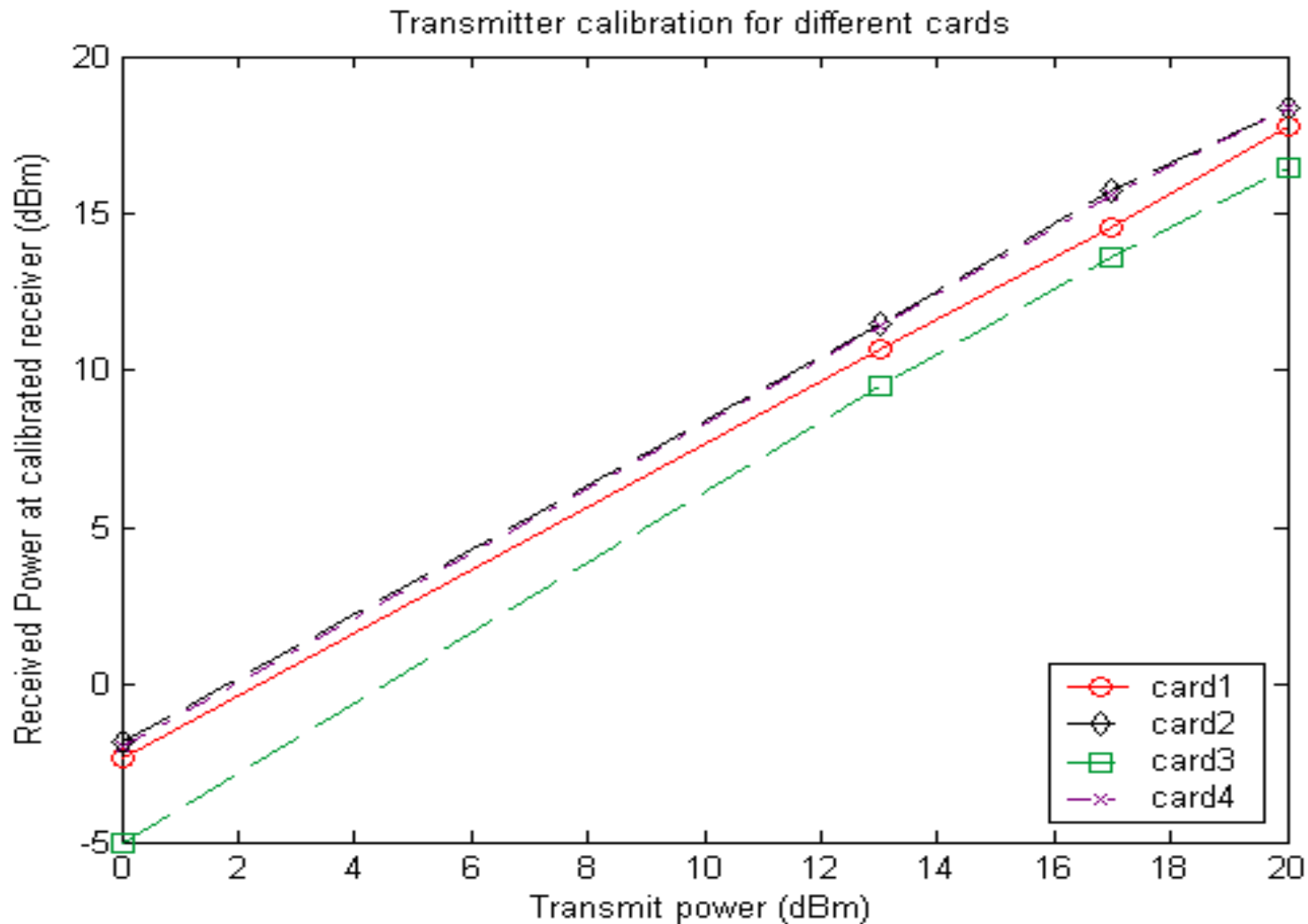
Agilent 89600S Vector Signal Analyzer (VSA) used as the calibrated receiver

For all cards

- Output of the cards connected through an RF-cable and a pair of connectors (with 2 dB attenuation loss) into the front end of the VSA
- The transmitting card fixed on channel one at four different power levels
- Sends a continuous stream of packets through the wireless interface
- The VSA measured the corresponding received band energy for each of the transmitter power settings

Transmitter calibration

Agilent 89600S Vector Signal Analyzer (VSA) used as the calibrated receiver



Note that received power is not corrected for the 2dB cable loss

Receiver calibration

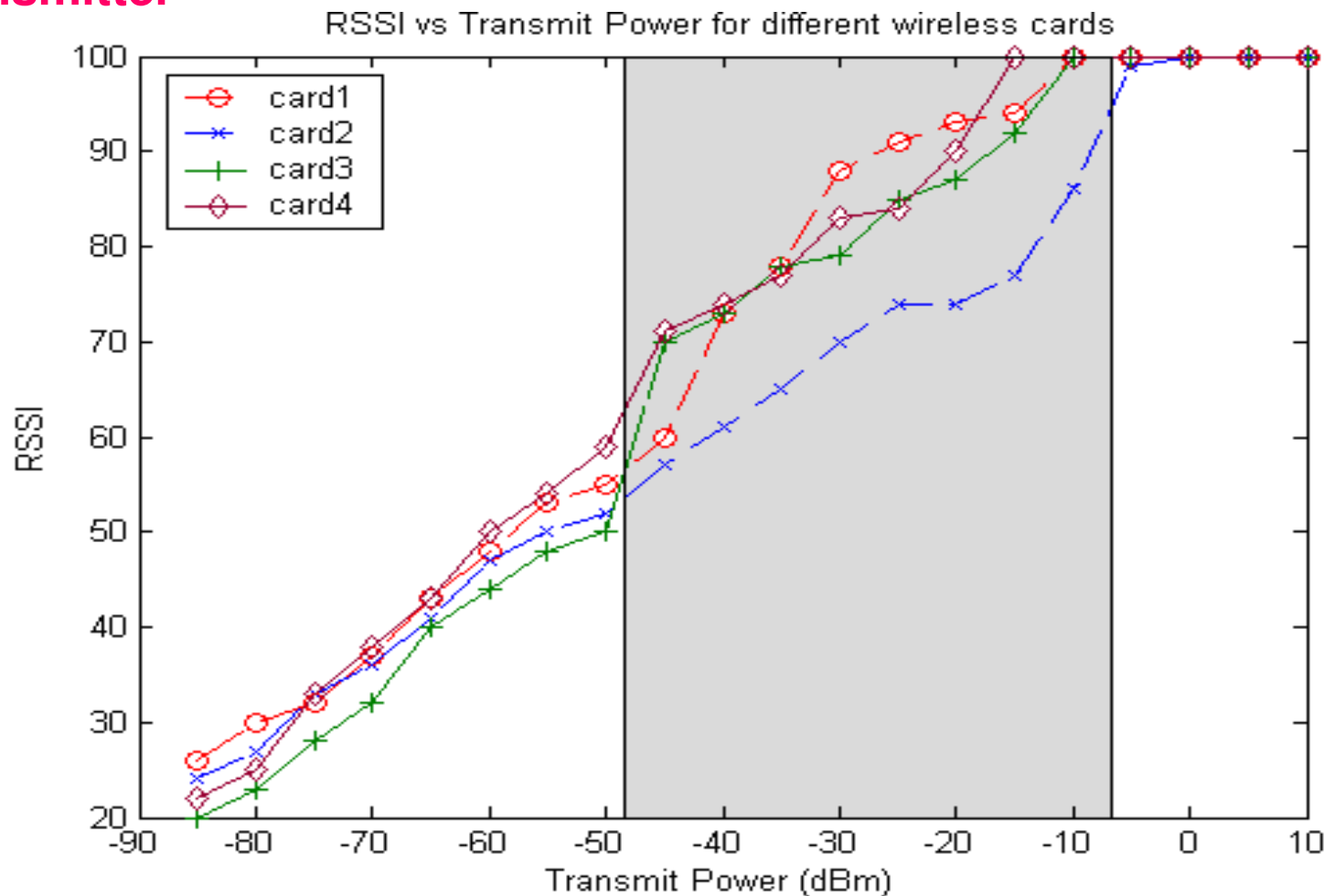
Agilent E4438C Vector Signal Generator (VSG) as the calibrated transmitter

For all cards

- **VSG injects modulated 59 byte 802.11b beacon at preset frequency**
- **VSG varies transmit power level from -85 dBm to 20 dBm**
- **Card under test reports the RSSI value for each packet**

Receiver calibration

Agilent E4438C Vector Signal Generator (VSG) as the calibrated transmitter



Note that the RSSI readings includes the 2 dB attenuation loss in the RF connector

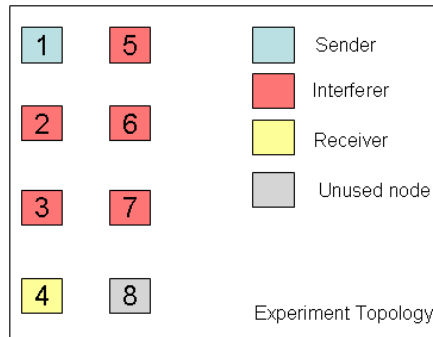
Tests to characterize repeatability

Run identical experiments

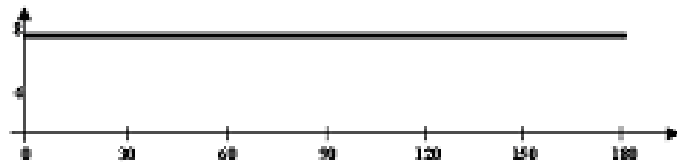
- Over the span of a month (to capture time variations)
- On different sets of nodes, while maintaining the same topology (in order to capture the spatial effects and other hardware issues)

Temporal repeatability

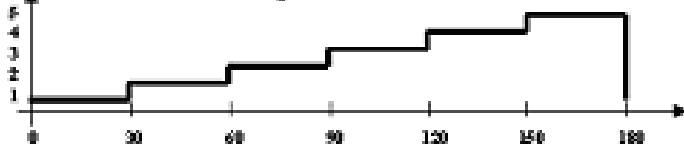
The Experiment



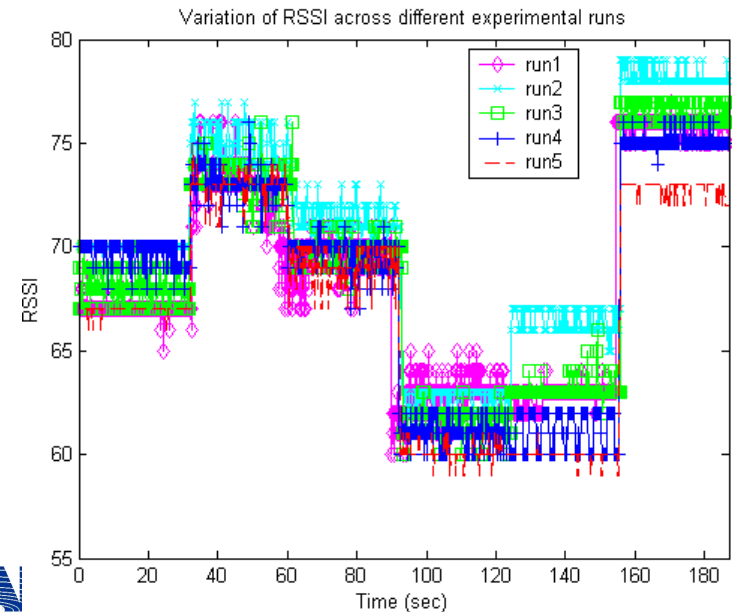
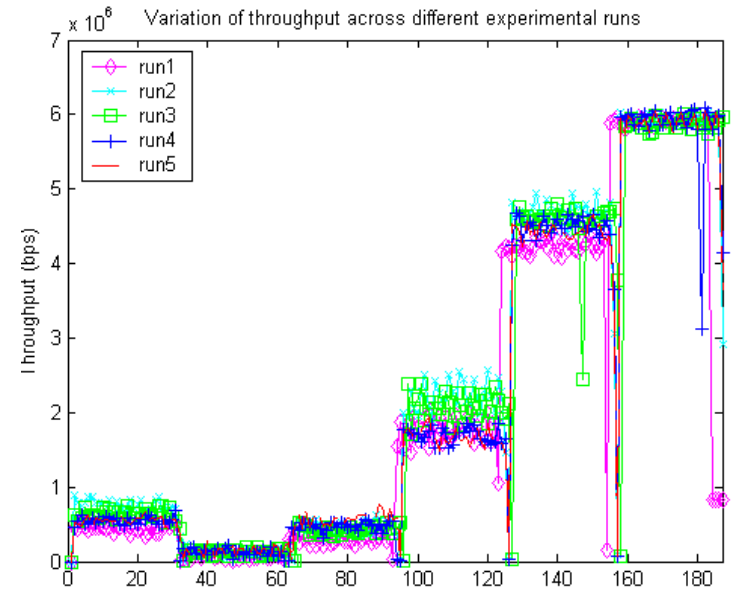
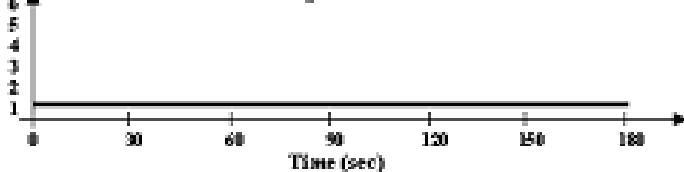
Offered Load On All Senders (Mbps)



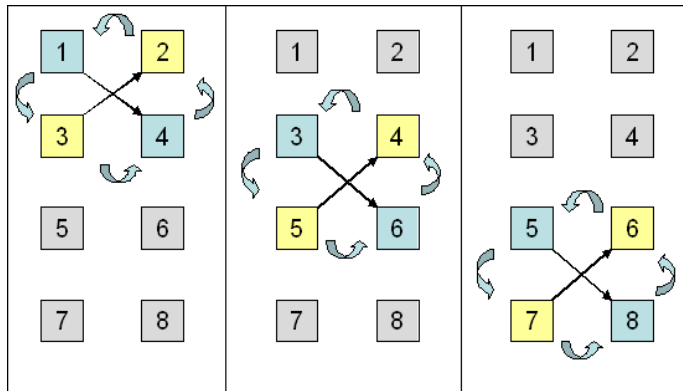
Channel Assignment On Obstructed Link



Channel Assignment On Interferers



Spatial repeatability



- Unused node
- Sender
- Receiver

Blue sender sends to blue receiver

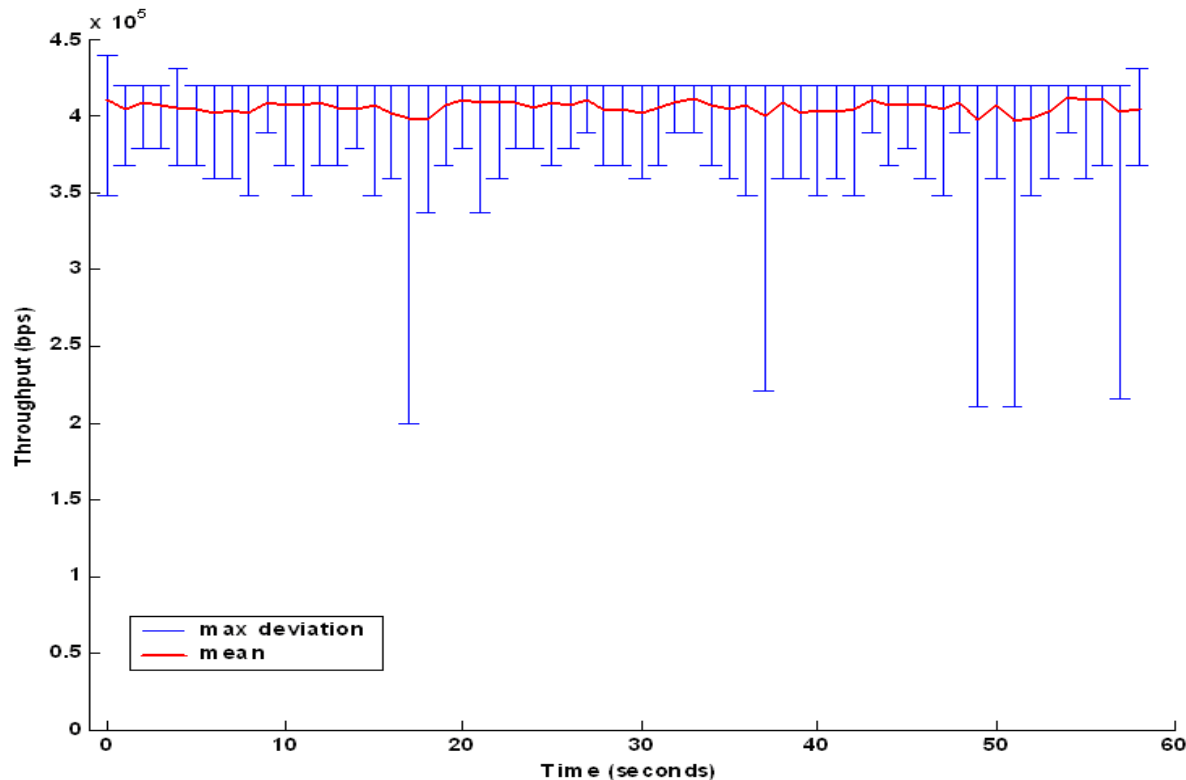
Yellow sender sends to yellow receiver

Experiment repeated on a different set of nodes with same topology

Arrangement 1

Arrangement 2

Arrangement 3



Spatial throughput variations w.r.t mean for experiment duration averaged over different experimental runs