A Proposed Software Standard for Design, Deployment and On-going Maintenance of In-building Communication Networks

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2002 International Symposium on Advanced Radio Technologies

Boulder, Colorado

March 4-6, 2002

Motivation for Indoor Wireless

- **Flexible, rapid network deployments are needed where people work**
- **Manufacturing and military environments are hostile, with noise, moving equipment and are difficult to maintain & keep clean.**
- **Building environments require networks to be hidden behind walls & above ceilings.**
- **Wireless communications will evolve as the primary medium for in-building & campus networks in the next decade.**

Why Campus/Indoor Wireless Coverage?

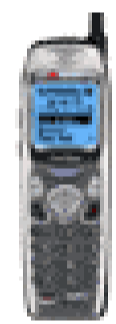
- Public areas, offices, classrooms need coverage
- Huge need to move in-building users onto in-building networks where interference is confined within building walls -- avoids saturation of outdoor network
- Consumers are adopting wireless appliances for ubiquitous coverage - capacity needed in buildings where people live, work, recreate
- Carriers and building/tower owners can offer savings through integrated services and billing

Wireless Access Issues in Buildings

- Buildings and Campus enterprises need planned wireless internet and cellular/PCS strategy.
- Campus environments require design tools that support ongoing facilities management and maintenance for expansion and upgrades.
- In-building wireless deployment in its infancy but will explode with Wireless Office, Wireless LANs, Wireless Video, VoIP, Bluetooth, and Wireless PDAs.

In-building Service Type

- Cellular, PCS, WAP
- Wireless Office Service
- Wireless LAN (IEEE 802.11)
- Wireless PDAs (Compaq IPAQ, Handspring)
- Wireless VoIP
- Wireless Video
- Bluetooth



Design Objectives

- RF Performance
- Cost
- Specific Customer Requests
- Ease of Installation
- Ease of Maintenance

Indoor RF Fading Statistics

Outdoor	Indoor
Rayleigh	Rician

Bottom Line:

- **Indoor Environment is More Forgiving**
- **Use 17 dB C/(I+N) for IS-136 or PDC**
- **Use 13 dB C/(I+N) for GSM or GPRS**
- **Use 7 dB C/(I+N) for IS-95 or CDMA 2000**
- **Lack of substantial multipath inside buildings renders RAKE useless**

Indoor Radio Noise Sources

- Computers
- Rotating Machines
- Power Distribution Equipment
- RF Heating Equipment
- Transmitters

Design/Planning History: Macrocell Design

- **Original use of planning tools was for outdoor cellular networks - RF design and planning.**
- **Planning decisions and tower placements could be simulated and analyzed prior to deployment.**
- **Design strategies and techniques improved.**
- **Cell tower placement became more efficient.**
- **Lacked asset management or document support.**
- **Difficult to track installed tower infrastructure.**

Millions of Buildings … So Little Time

- How can we quickly design systems?
- How can we compare technologies?
- How can we save and communicate designs?
- How will integrators become designers?
- How will vendors verify design guidelines?
- How will building owners track hardware?
- How will we manage and maintain the in-building infrastructure?

VA Tech MPRG Research

- **Early in-building propagation work.**
- **Decade of measurement experience.**
- **Decade of modeling and optimization experience.**
- **Decade of Industry suggestions and practical advice.**
- ***SitePlanner* is the result of over 30 years of student research.**

VA Tech MPRG Research (cont.)

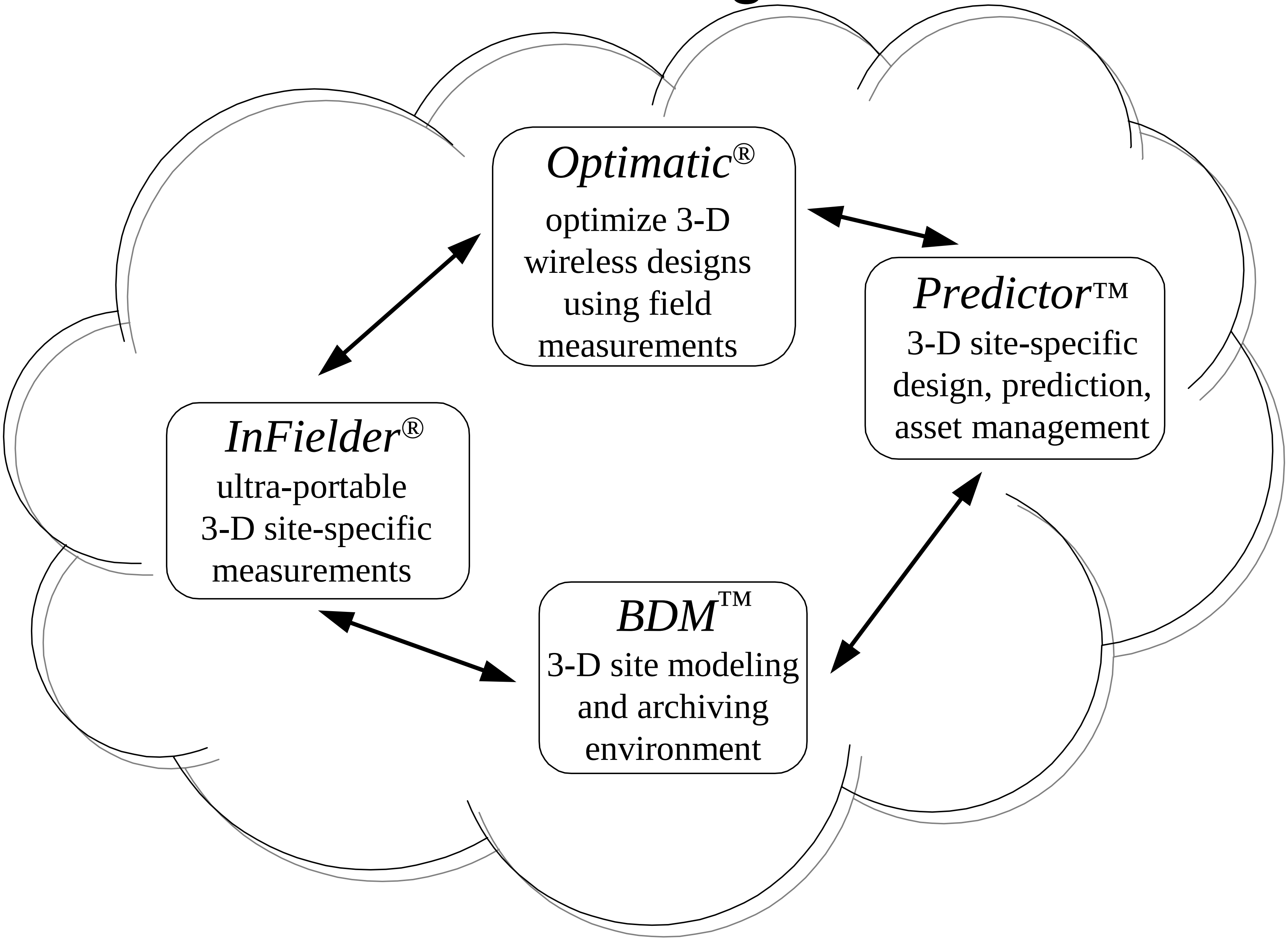
- **MPRG students and staff researchers have contributed to the body of knowledge used in the *SitePlanner* concept:**

  Scott Seidel, Joe Liberti, Dwayne Hawbaker, Ken Blackard, Alan Fox, Roger Skidmore, Idine Ghoreishain, Greg Durgin, Neal Patwari, Ray Lovestead, Ben Henty, Brian Gold, Charles Lepple, Bob Boyle, Kirk Carter, Juin Siew, Wesley Rios, Manish Panjwani

SitePlanner: Planning, Design, and Management for In-Building Networks

- **Provides rapid system design of complex technologies while minimizing costs and meeting coverage and capacity needs.**
- **Indoor wireless coverage is non-intuitive and complex, but SitePlanner provides huge cost/time savings and rapidly trains the user.**
- **SitePlanner allows flexibility and rapid "what if" designs to meet specific needs of customers.**
- **Easy visualization of proposed systems.**
- ***SitePlanner* provides *simultaneous* performance analysis, wireless equipment tracking, project documentation, and asset management!**

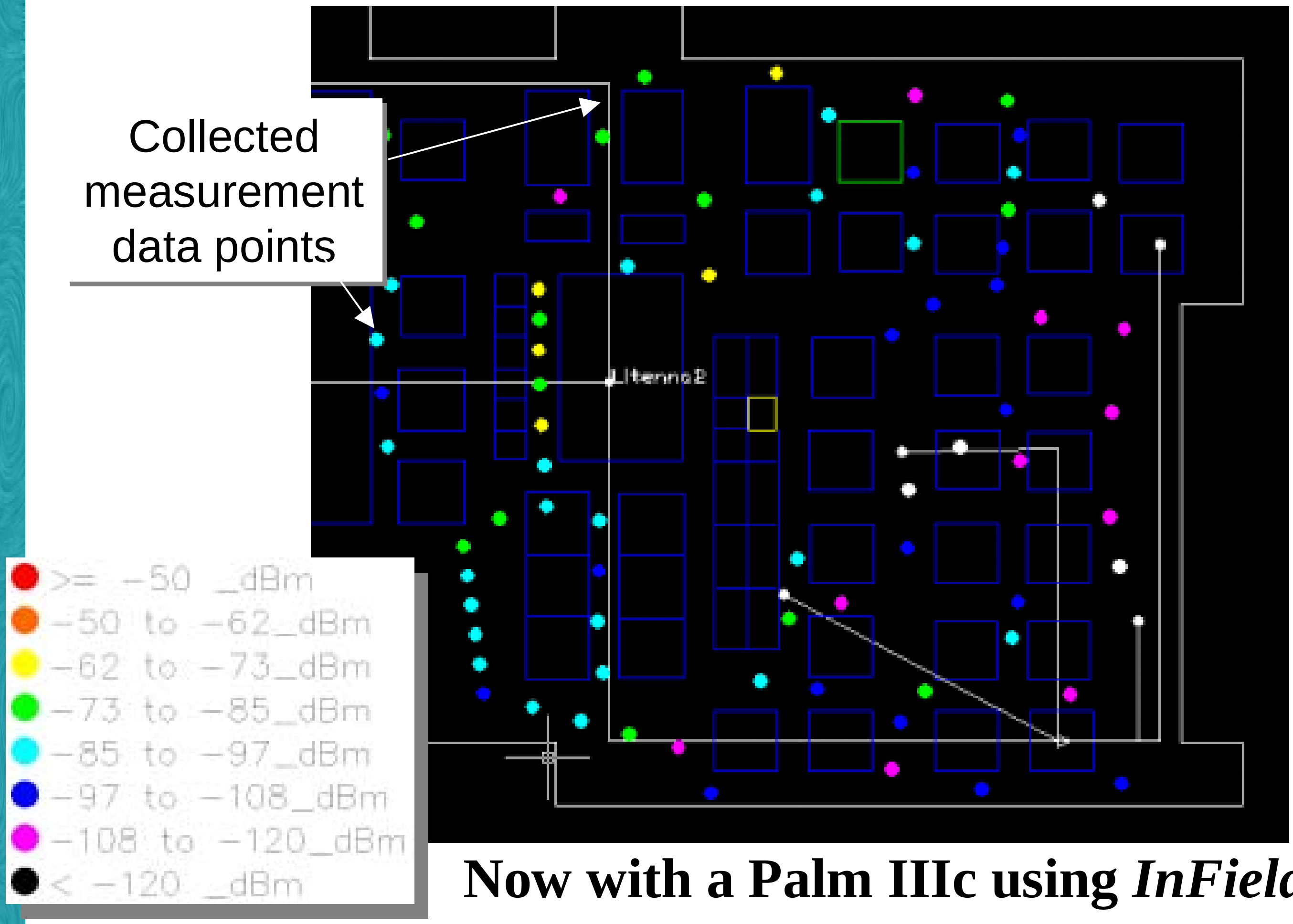
The *SitePlanner*® Design Environment



Common Uses of *SitePlanner*

- **Common software platform provides sharing of designs and "as-builts" throughout an organization or across users on a project.**
- **Allows vendors, consultants, integrators, and manufacturers to share and archive designs.**
- **Provides an objective "level playing field" for all in-building design, deployment, and optimization work.**
- **Allows new hires or inexperienced personnel to become rapidly proficient in the field of in-building wireless design, specification, or integration.**
- **Provides retrievable records of all aspects of an in-building project, for quality audits and maintenance.**
- **SitePlanner can be shared by engineers, facilities managers, and accounting staff from cradle-to-grave.**

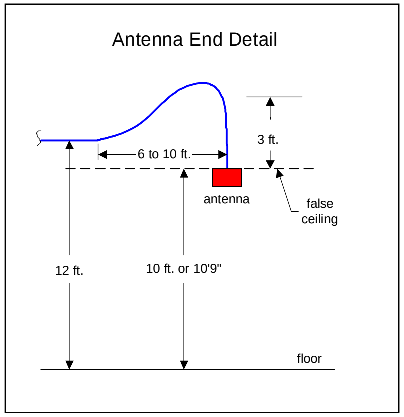
Quick and Easy Data Collection

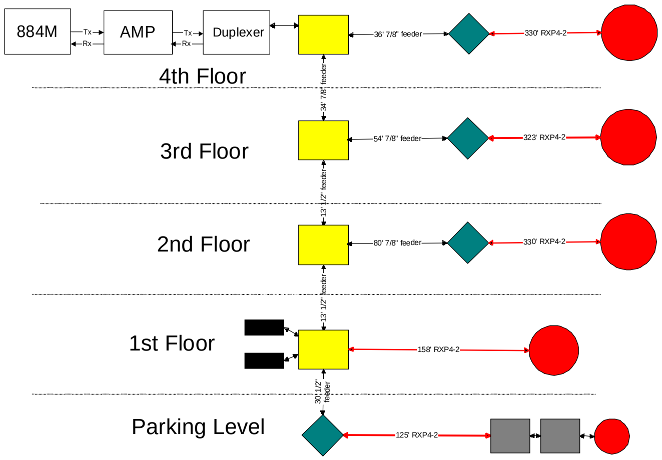


Now with a Palm IIIc using *InFielder*® *PDA*

Documenting Your Design

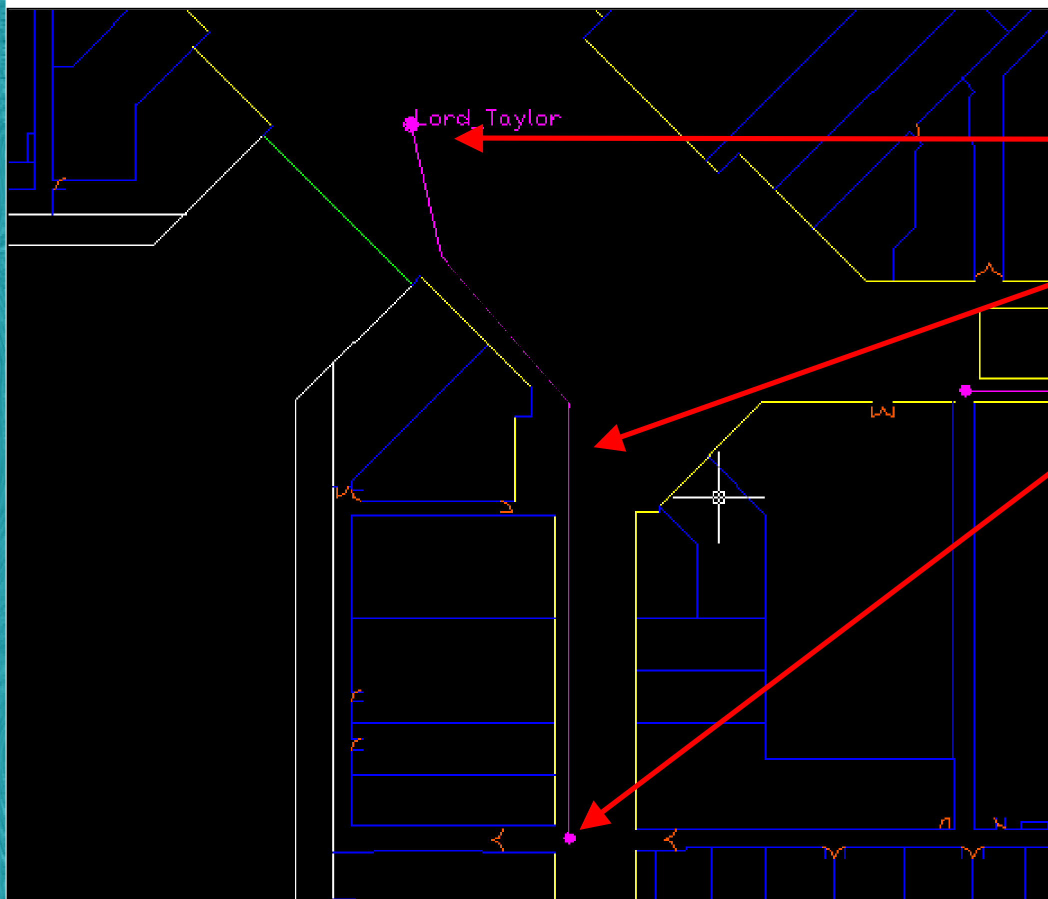
- ➢**Plans**
- ➢**Legend**
- ➢**Detail Drawings**
- ➢**Backbone Diagram**
- ➢**Bill of Materials**
- ➢**Photo Sims**
- ➢**Files Stored Safely**





***SitePlanner®* does all of this!**

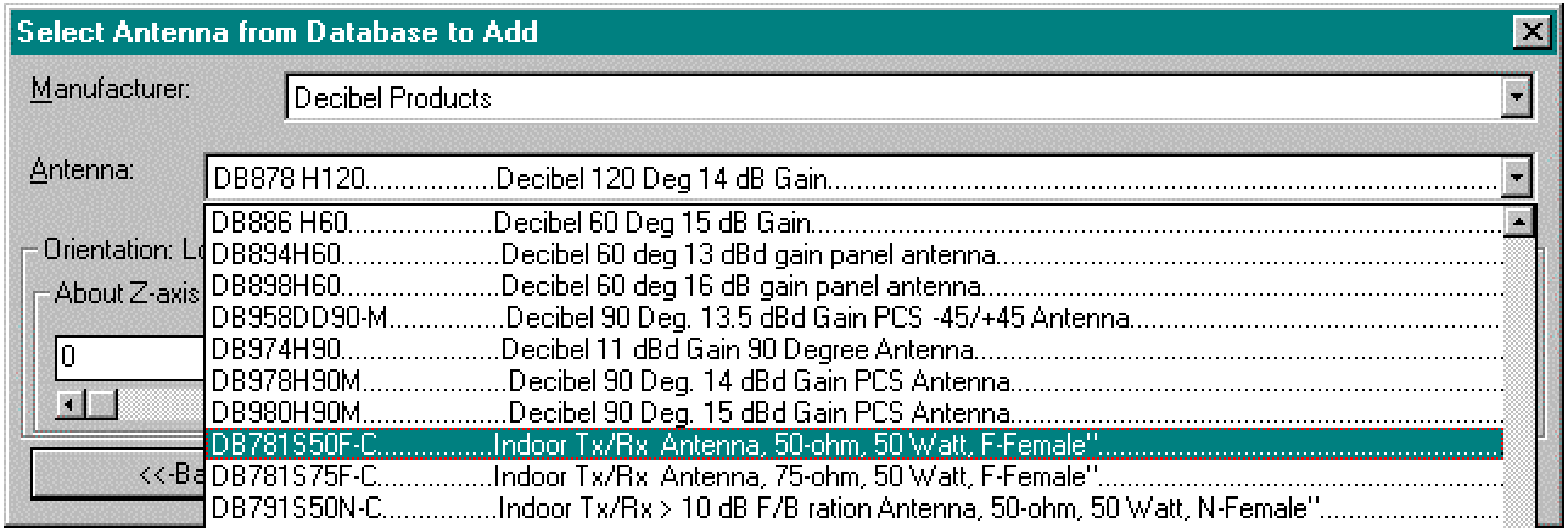
SitePlanner® Graphical System Design



Components are picked from a customizable Parts List Library consisting of more than 3,000 components from over three dozen manufacturers

Point and click with the mouse to visually position wireless system components such as cables, antennas, amplifiers, splitters, in the building!

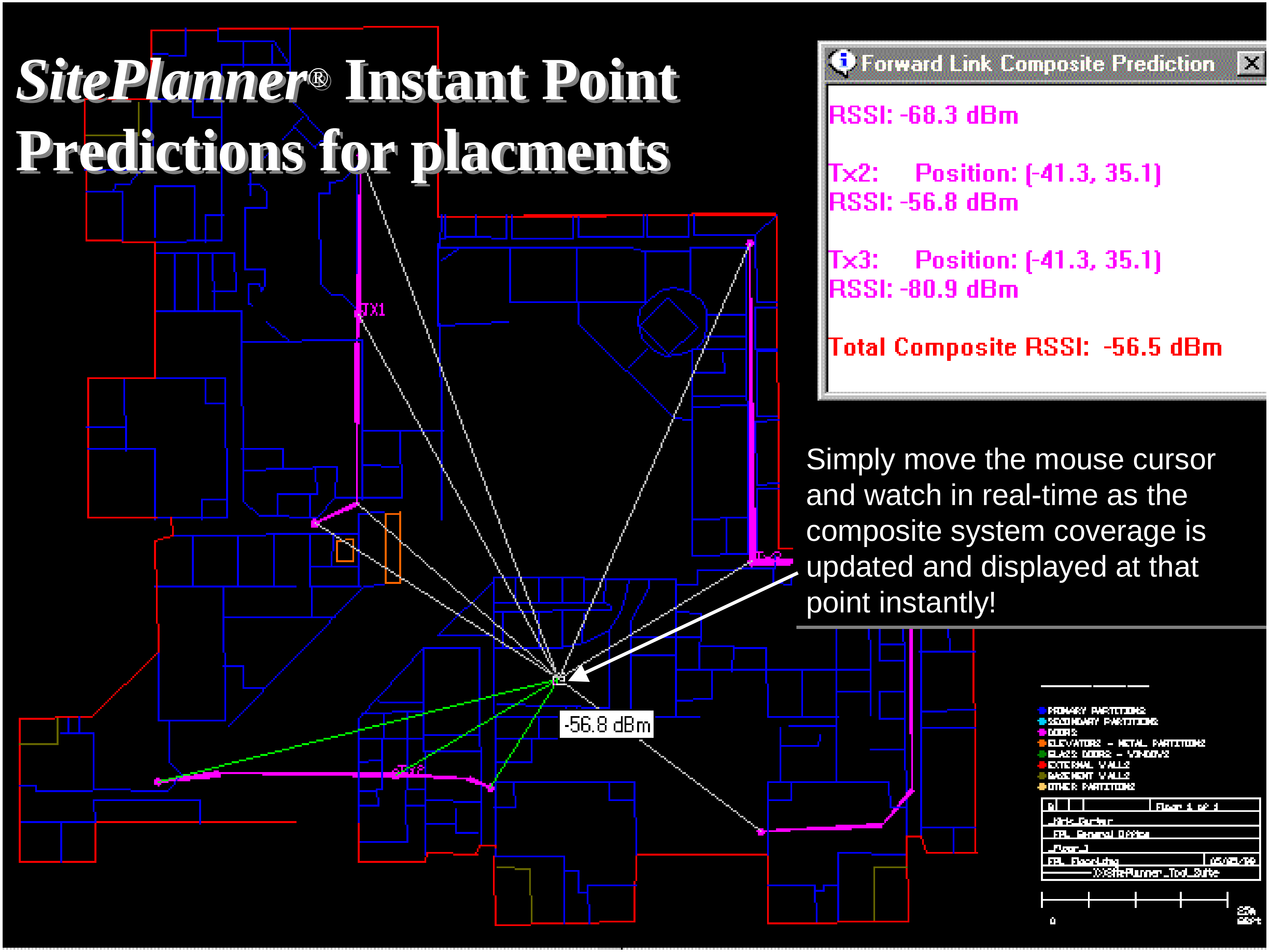
SitePlanner® Built-in Components Database



Parts List Library contains thousands of antennas, amplifiers, cables, splitters, and leaky feeder antennas.

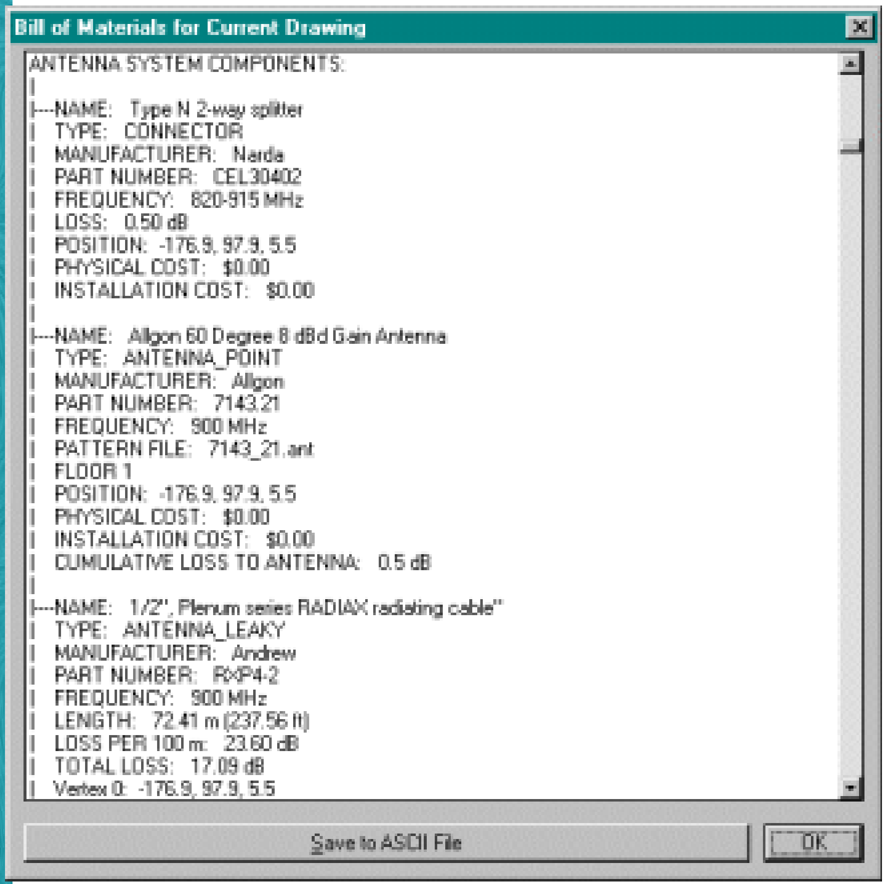
Quickly and easily analyze design tradeoffs in terms of cost and performance with the click of the mouse, while creating a complete bill-of-materials and cost analysis.

SitePlanner® Instant Point Predictions for placments



Simply move the mouse cursor and watch in real-time as the composite system coverage is updated and displayed at that point instantly!

Automatic Bill of Materials



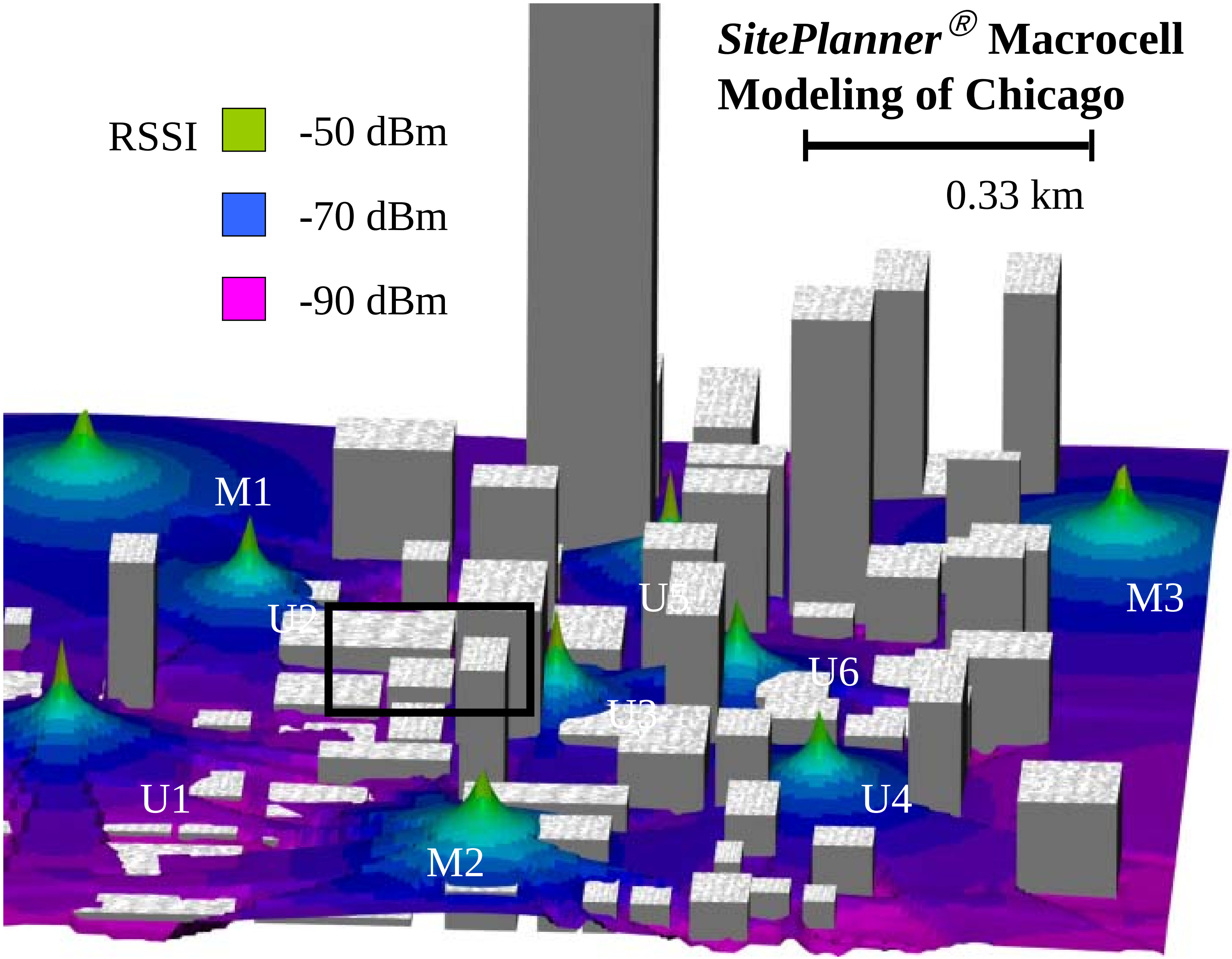
SitePlanner® **Automatically tracks full bill of materials for your design**

Automatically tracks both physical and installation cost for all components

Enables least-cost design

Capabilities of SitePlanner

- Accurate prediction of Signal, Interference
- Allows frequency planning and management
- Documents and archives network layout
- Transportable for users throughout enterprise
- Provides cost and performance data in a single, integrated software environment
- Useful for all wireless or wired technologies within a building or campus environment



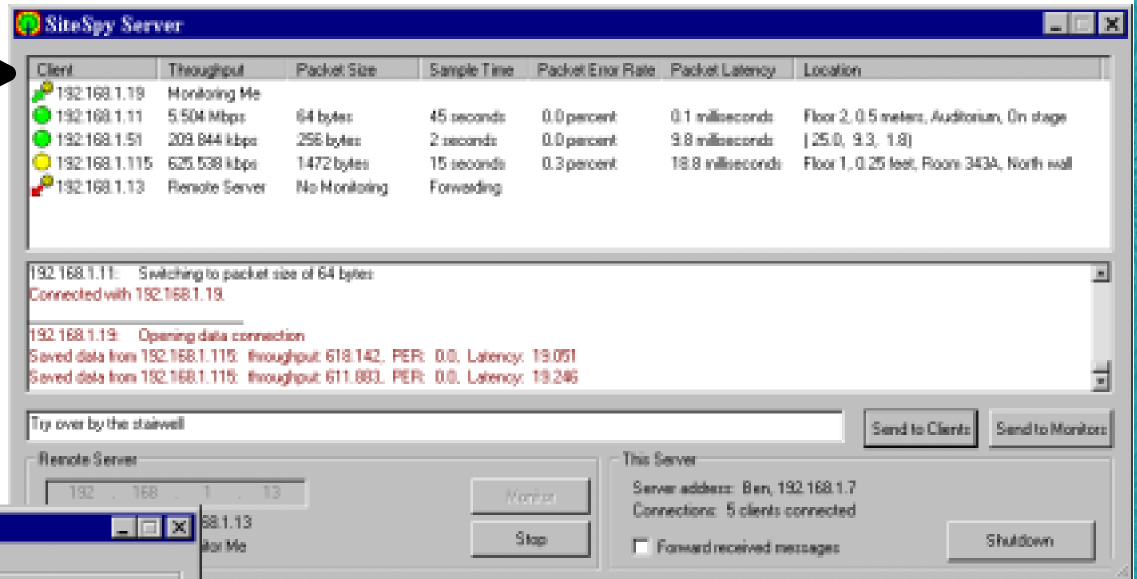
SitePlanner® Macrocell Modeling of Chicago
RSSI
-50 dBm
-70 dBm
-90 dBm
0.33 km
M1
M2
M3
U1
U2
U3
U4
U5
U6

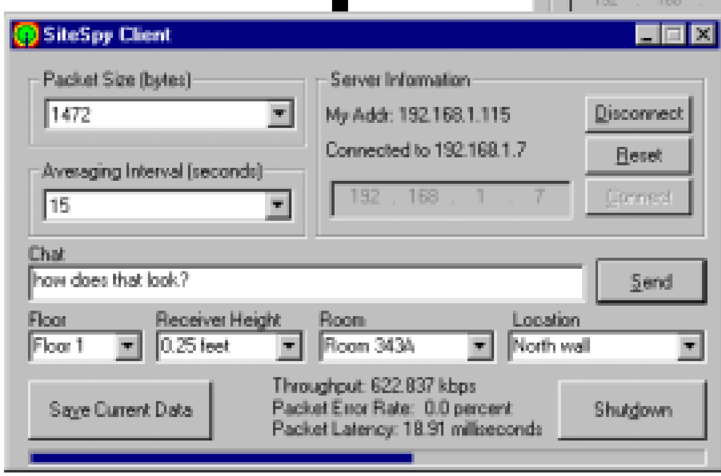
Predicting Data Throughput

- SitePlanner predicts RSSI but often we are interested in actual user data throughput
- We desired to identify gross features between predicted RSSI values, number of network users, and end user throughput in IEEE 802.11b networks.
- The SitePlanner environment supports general modeling for measurement data
- We developed network measurement tools that could measure end user throughput and RSSI simultaneously.

Wireless LAN Planning: *LANFielder*™ and *SiteSpy*™ Overlay with SitePlanner

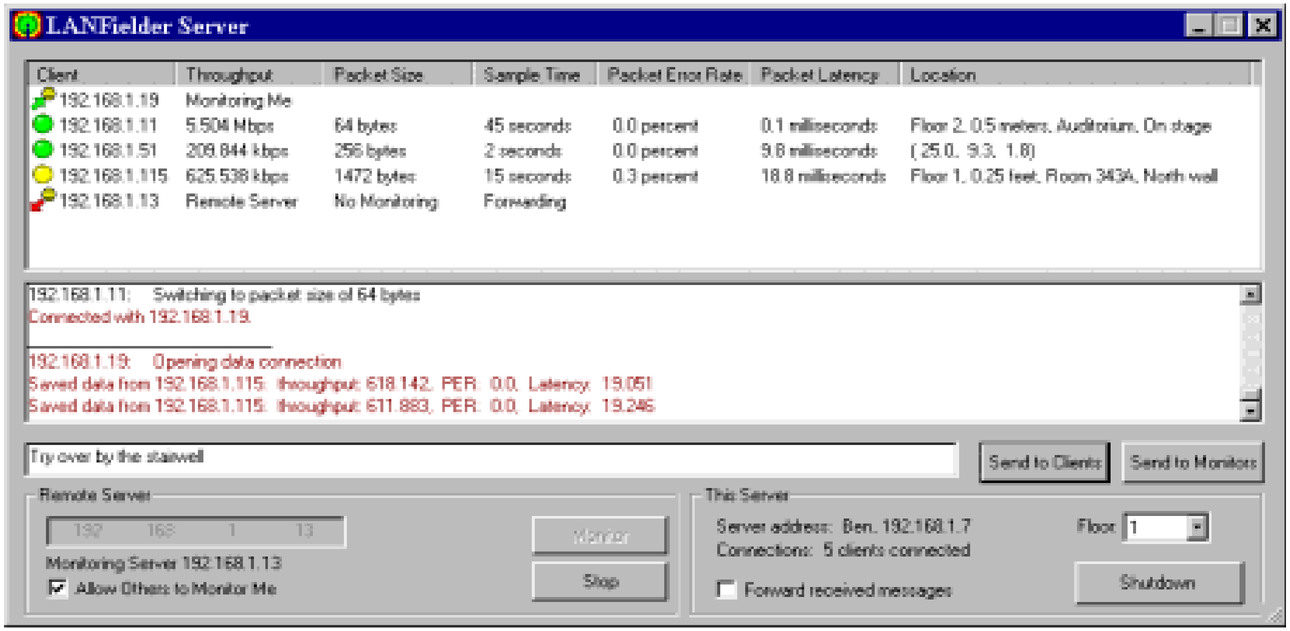
Measurement results that you can understand without being an RF Engineer





Provides wireless data network measurement using client/server technique

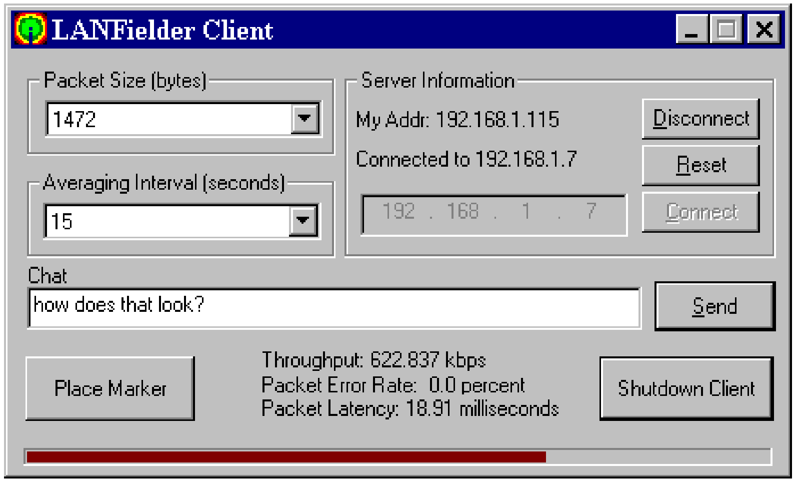
LANFielder Throughput Measurement Software



- Client/Server based architecture
- Server can be left unattended and echoes all test packets back to clients
- Allows field measurements that can benchmark and optimize network

Test Packet Format

- **Client transmits test packets to server**
- **Data payload can be varied in size**
- **Test packets transmitted during variable averaging interval**



PHY Preamble 9 bytes	PHY Header 6 bytes	MAC Header 34 bytes	Ethernet Header 14 bytes	IP Header 20 Bytes	UDP Header 8 Bytes	Data Payload up to 1472 bytes	MAC Footer 4 bytes

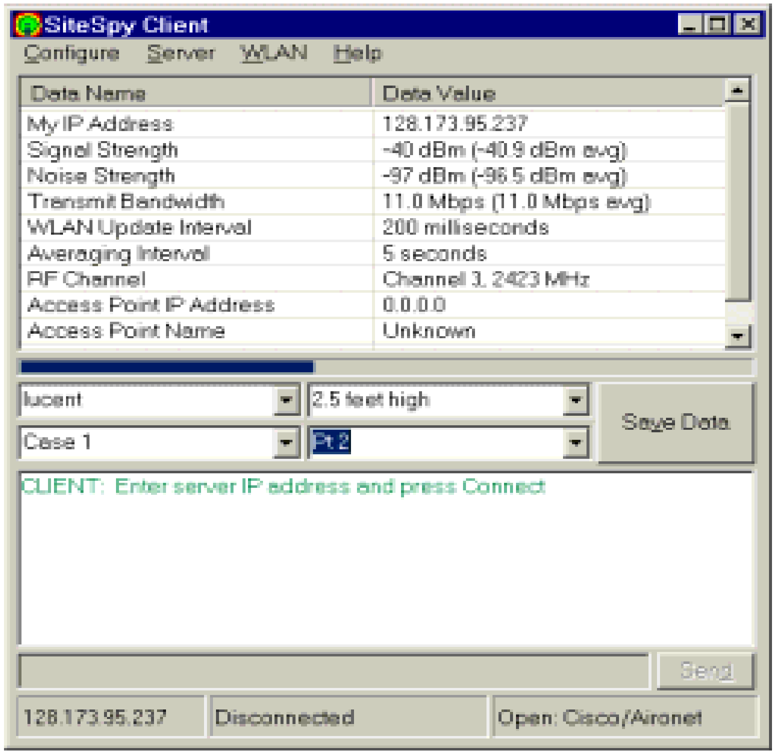
1 Mbps | 2 Mbps | 2, 5.5 or 11 Mbps

Virginia Tech
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

MPRG

RSSI Measurement Software (SiteSpy)

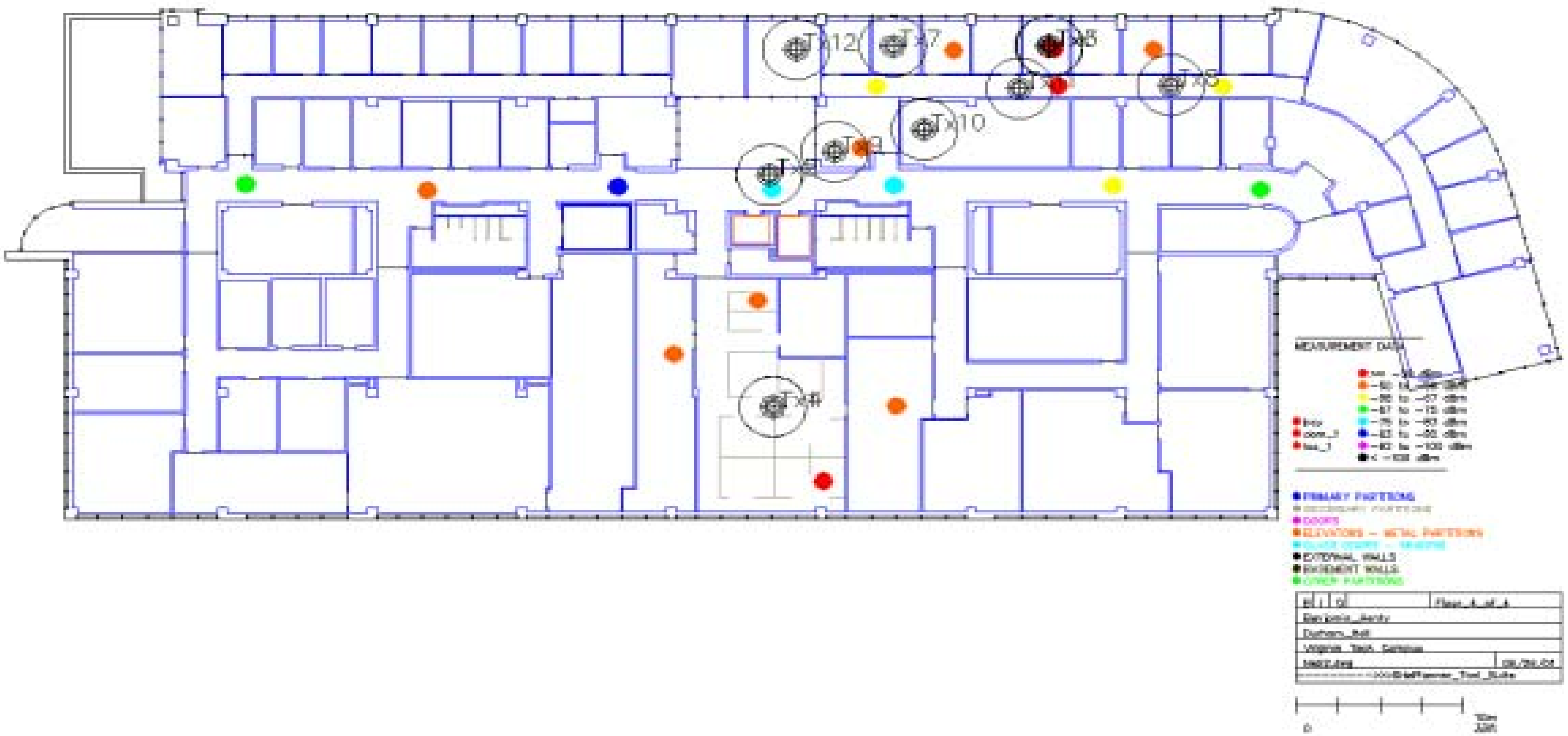
- **Uses an API to a CISCO Aironet wireless LAN card to measure signal strength, noise power, and wireless LAN operating parameters**
- **Frequent polling of received signal strength and noise power for accuracy**
- **Remote network monitoring**



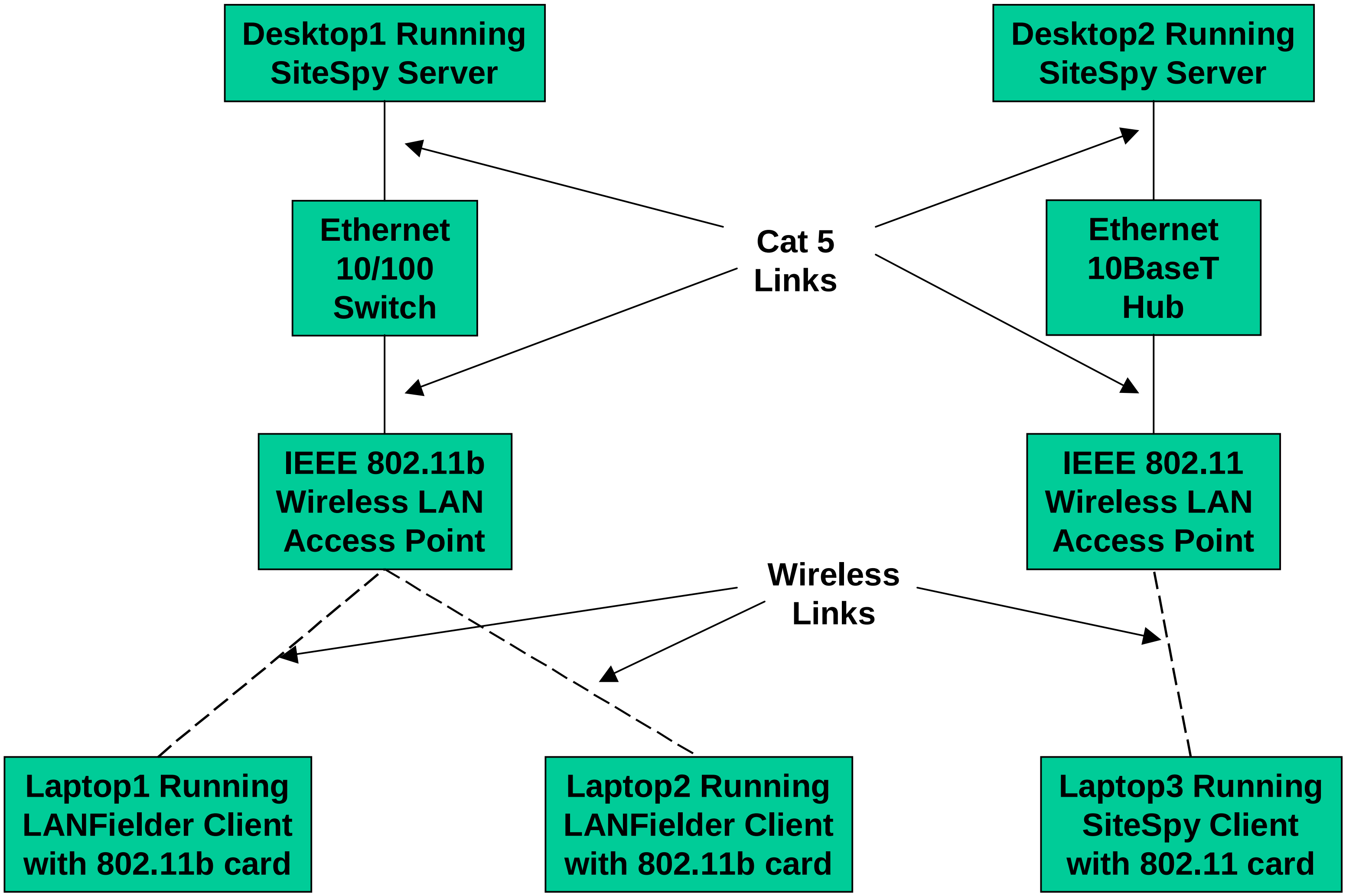
Measurement Campaign

- ***LANFielder*** **and *SiteSpy* used in a measurement campaign of two testbed IEEE 802.11b Systems:**
  - WaveLAN ORiNOCO (Lucent)
  - 3Com AirConnect
- ***LANFielder*** **used to record measurements in a campaign designed to explore a typical wireless LAN installations**
- ***SiteSpy*** **used with an interference system consisting of a DSSS IEEE 802.11 BayNetworks equipment to generate interference**

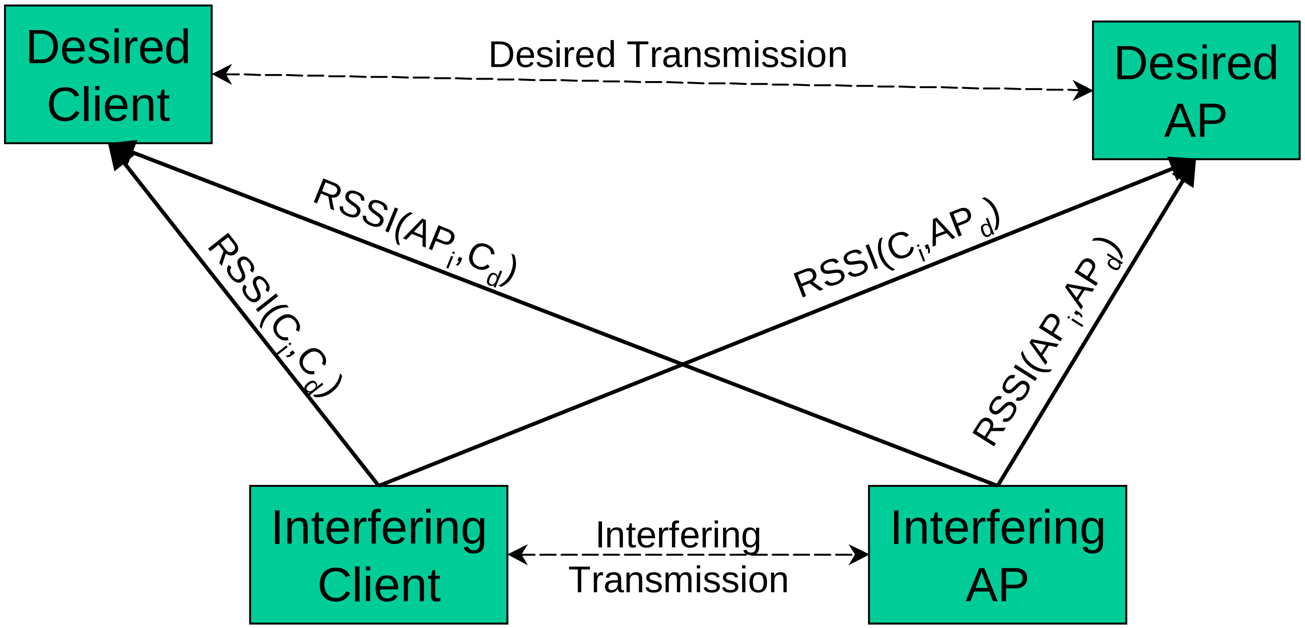
SitePlanner Model of Environment with RSSI Measurements



Throughput Measurement Setup



Quantifying Net Interference



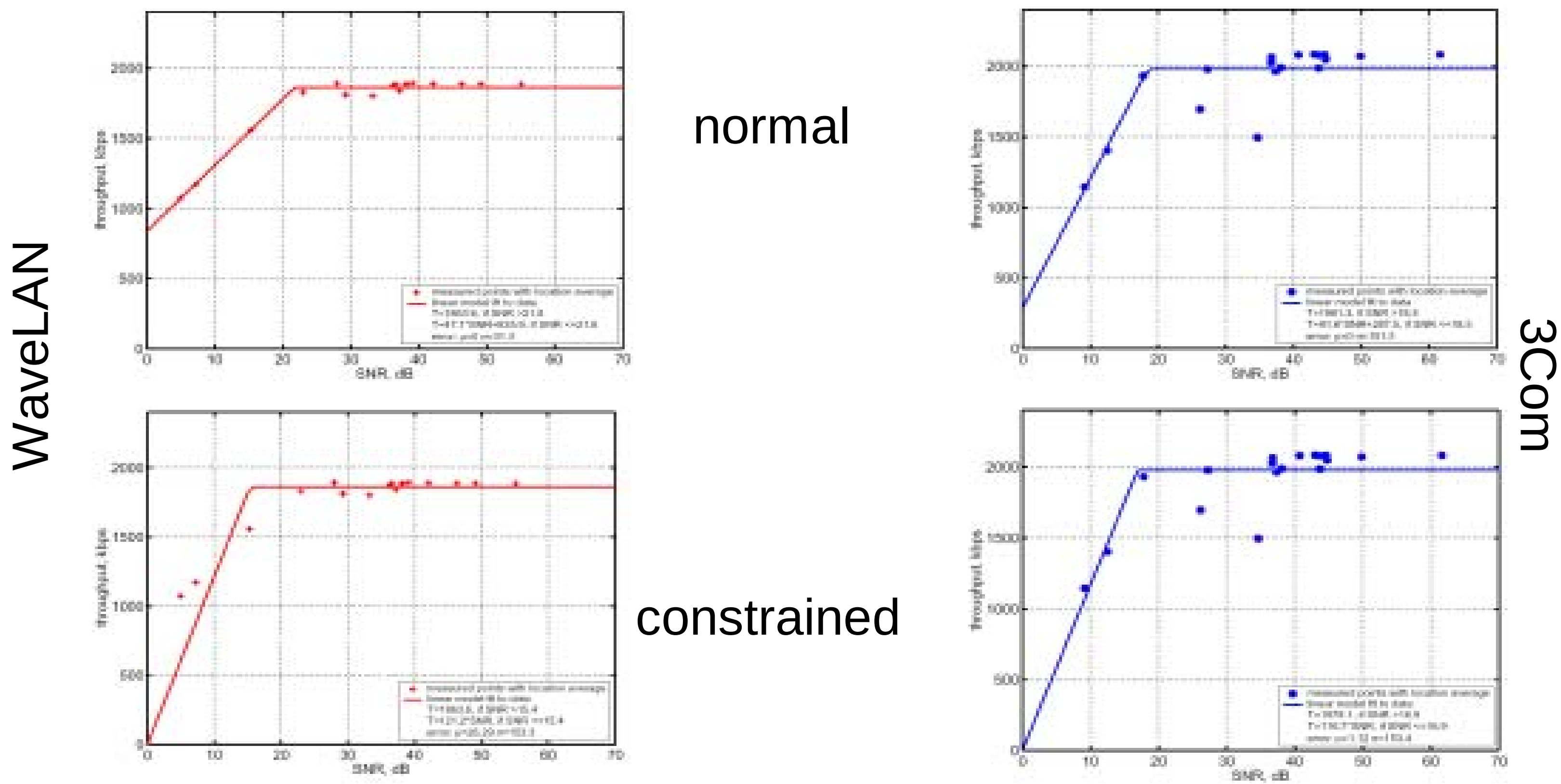
$$SIR_{net} = \frac{RSSI(AP_d, C_d)}{mean(RSSI(AP_i, AP_d) + RSSI(C_i, AP_d)), RSSI(AP_i, C_d) + RSSI(C_i, C_d))}$$

Source: B. Henty, "Throughput Measurements and Empirical Prediction Models of IEEE 802.11b Wireless LAN (WLAN) Installations," Master's Thesis, Virginia Tech, Blacksburg, VA, MPRG-TR-01-08, August 9, 2001.

Throughput Prediction Models

- Prediction models developed based on measurement campaign data.
- MATLAB used to compute model parameters based on best fit and local minima fit techniques.
- Models designed to be intuitive and easy to implement in software prediction tool.
- Constrained models were also considered which predict zero throughput when SNR reaches zero.

Linear Model Mapping SNR to Throughput



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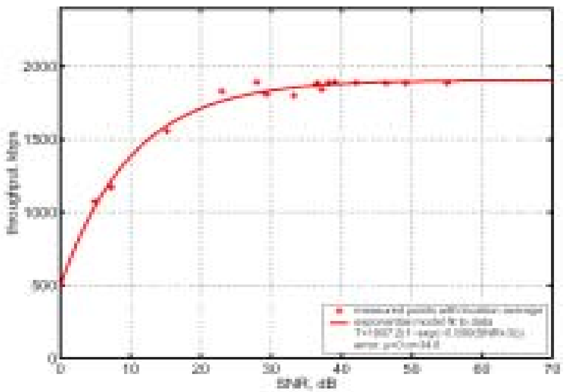
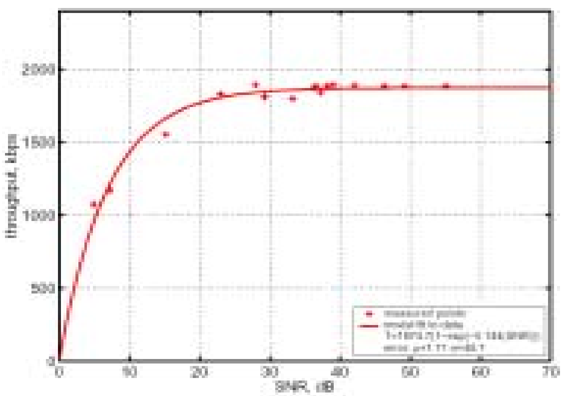
Exponential Model Mapping SNR to Throughput

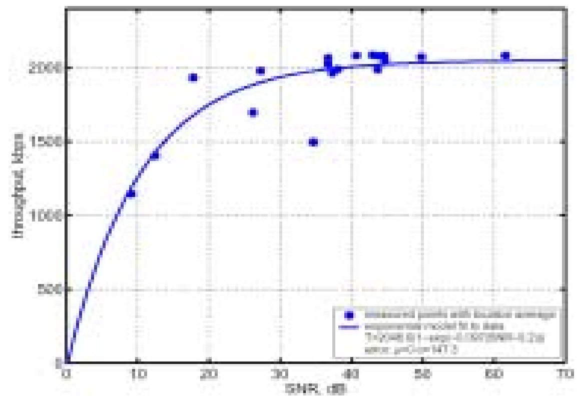
WaveLAN



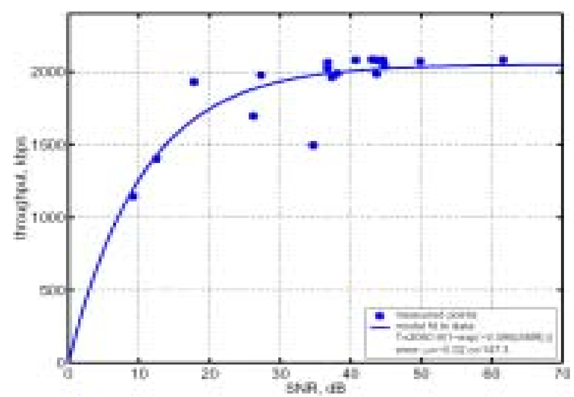
normal



3Com



constrained



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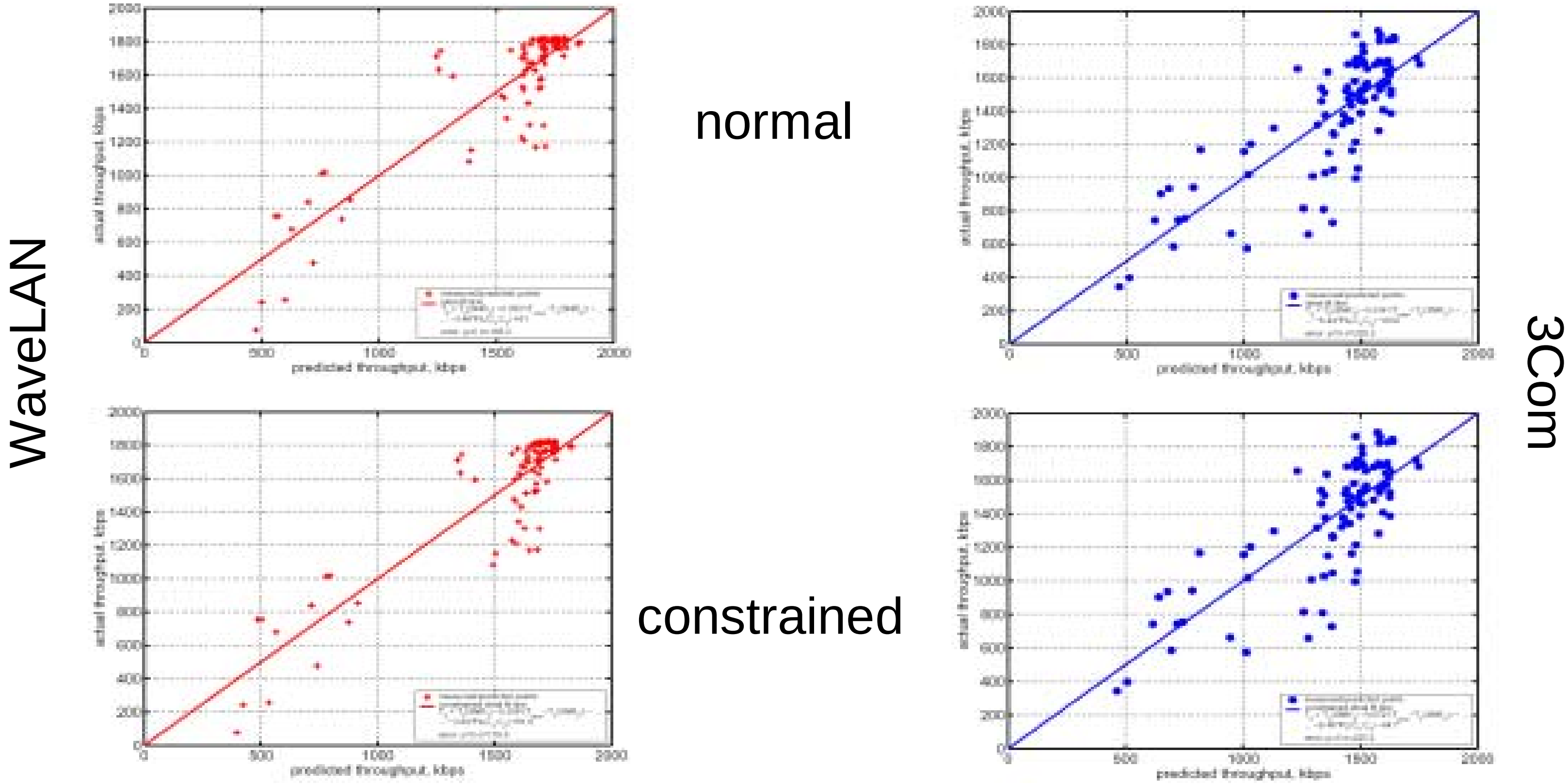
Two User Results, Multiple Users and Access Points



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Interference Model

$$T_i(SNR, SIR) = T_1(SNR) - T_{loss-int}(SIR)$$

$$T_{loss-int}(SIR) = A_i * SIR + B_i$$

- **Based on single user model**
- **$T_{loss\text{-}int}$ added to reflect loss in throughput due to nearby interfering wireless LAN**
- **SIR calculated as described previously and using the following equation:**

$$SIR_{net} = \frac{RSSI(AP_d, C_d)}{mean(RSSI(AP_i, AP_d) + RSSI(C_i, AP_d)), RSSI(AP_i, C_d) + RSSI(C_i, C_d))}$$

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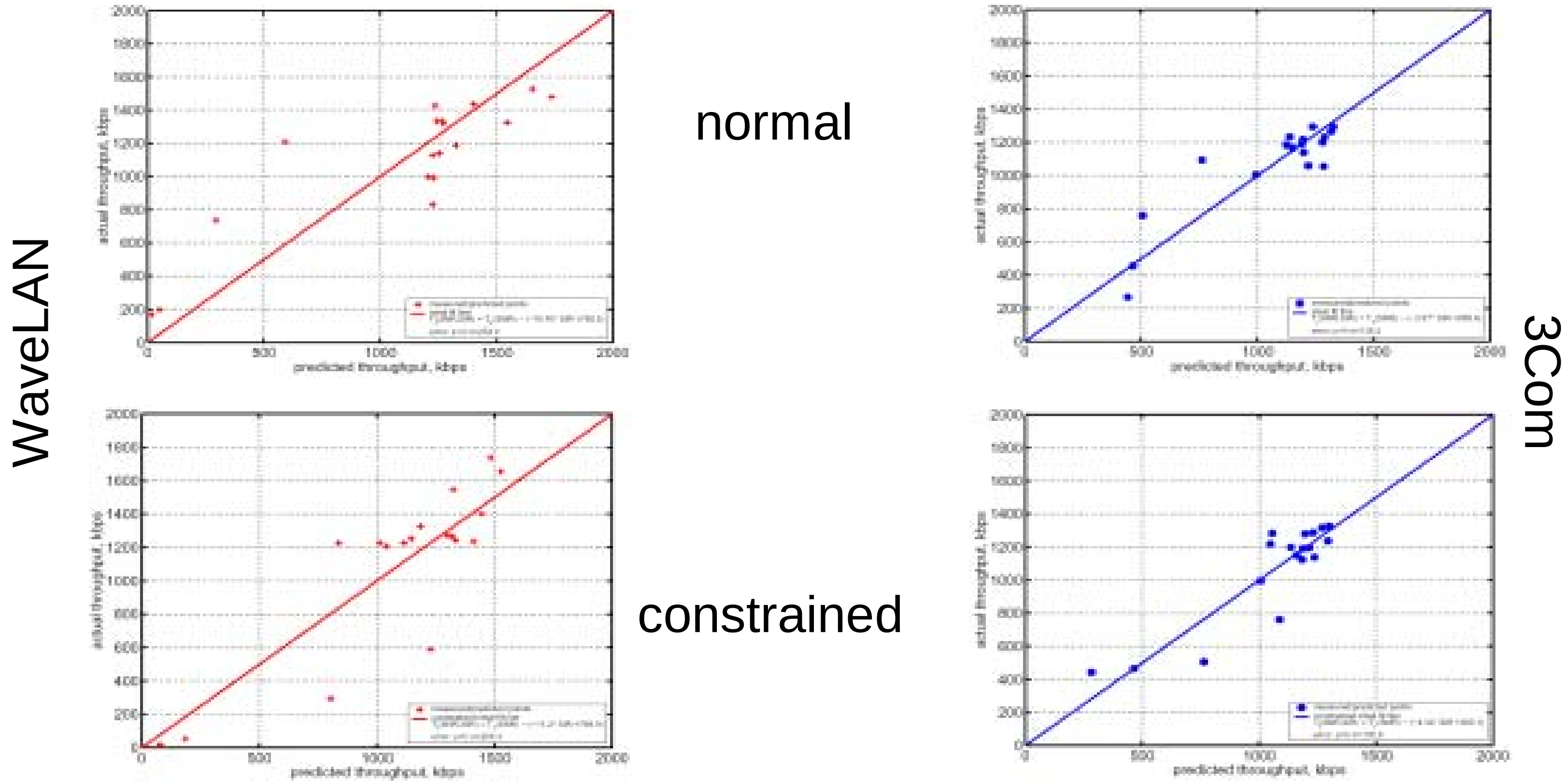
Interference Model Results



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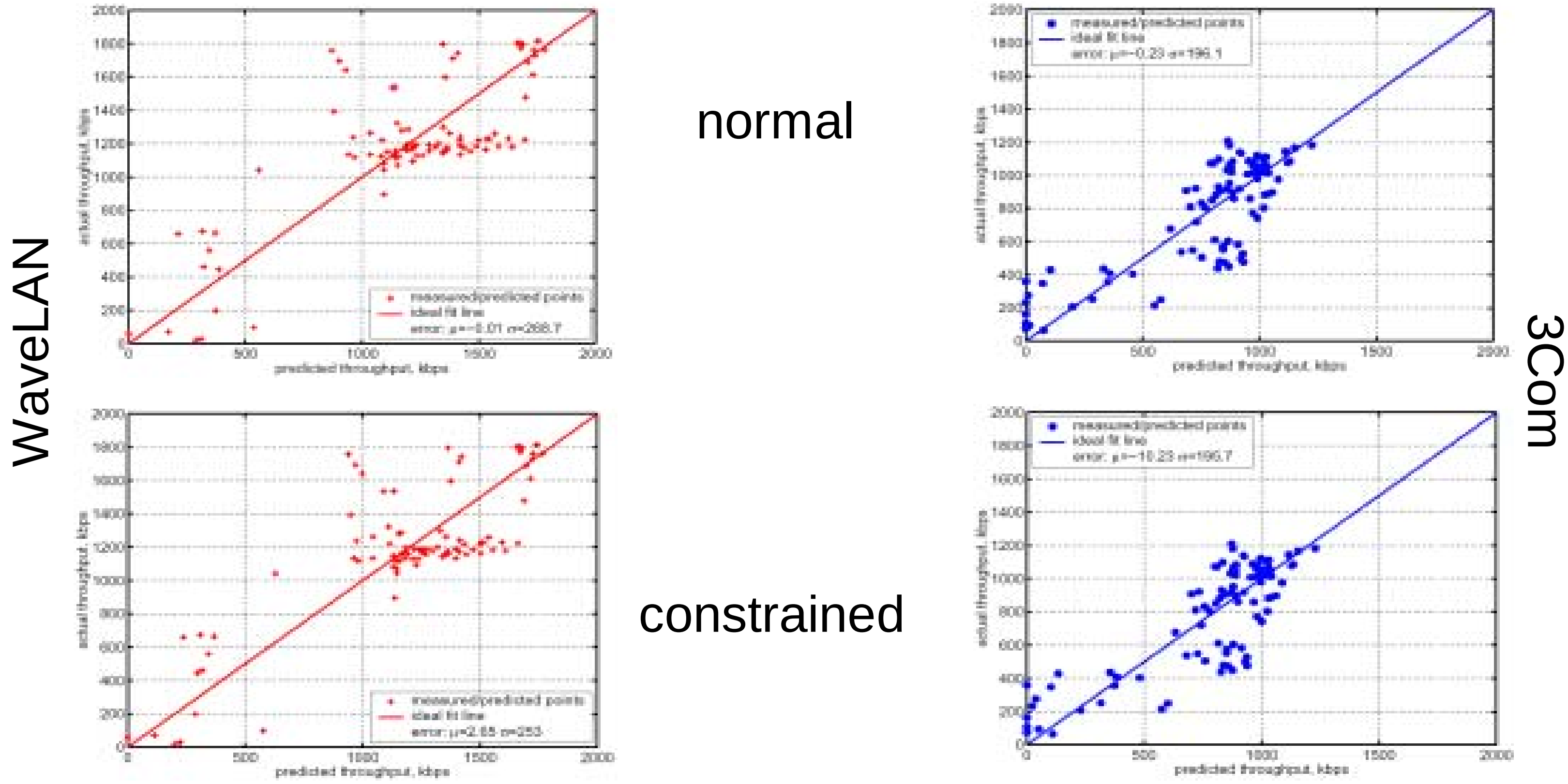
Two User with Interference Model
Multiple Users and Access Points



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Predicting Throughput Directly from Predicted RSSI and Interference Values from SitePlanner

- Throughput was predicted directly from a model of the measurement environment
- Predictions performed by combining Motley-Keenan[1]/Siedel-Rappaport[2] pathloss model with developed throughput models
- Results show accurate prediction of site-specific throughput

1 Motley, A. J.; Keenan, J. M. P. "Personal Communication Radio Coverage in Buildings at 900 MHz and 1700 MHz," Electronics Letters. Vol 4, Issue 12, p. 763-764, Jun 1998.

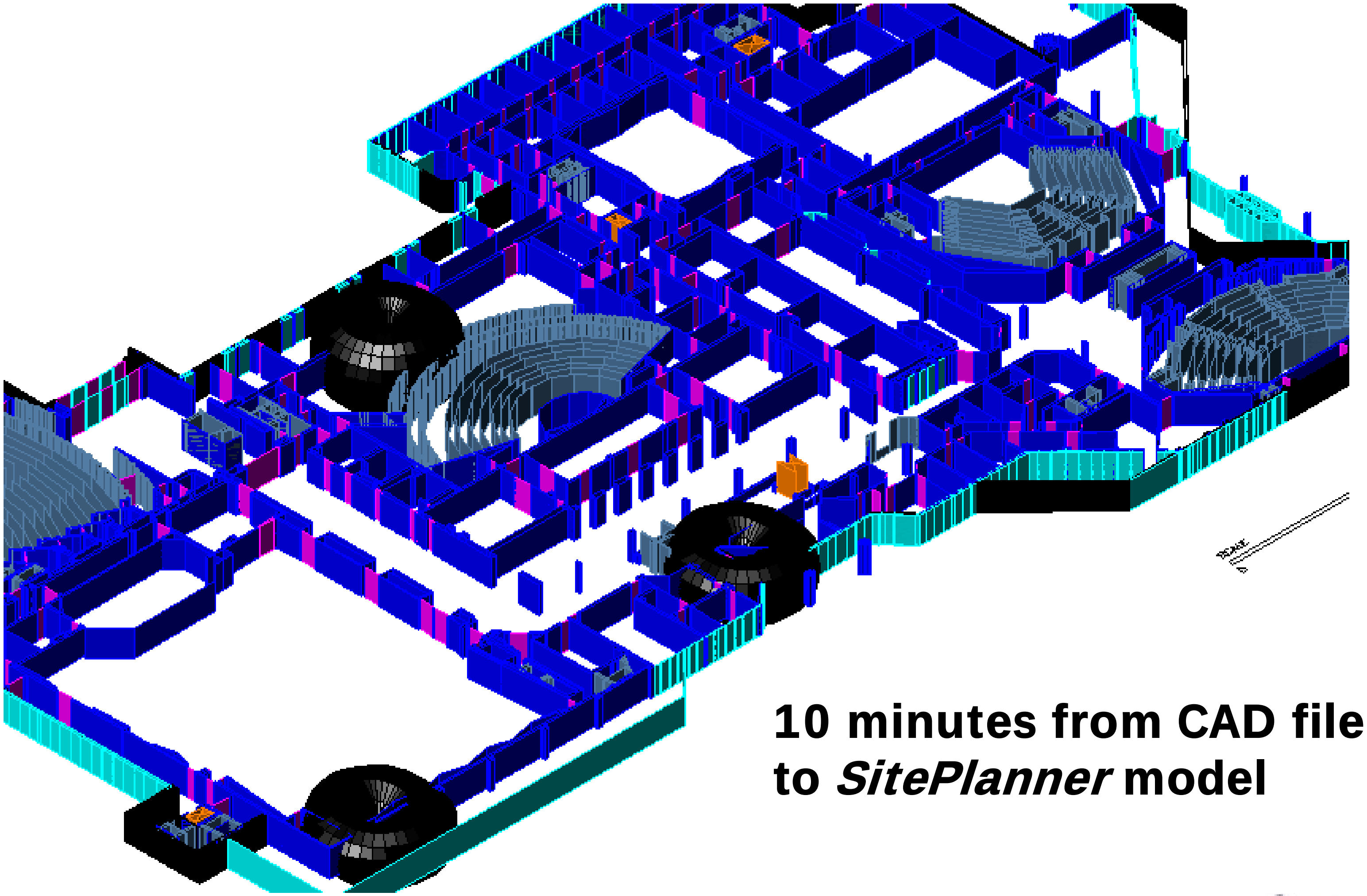
2 Seidel, S. Y., Rappaport, T. S., "914 MHz Path Loss Prediction Models for Indoor Wireless Communications in Multifloored Buildings." *IEEE Transactions on Antennas and Propagation*, Vol. 40, No 2, p.207-217, Feb 1992.

Case Study: WLAN Design

- 100,000 sq. ft., multi-story academic building on the University of Virginia Tech campus.

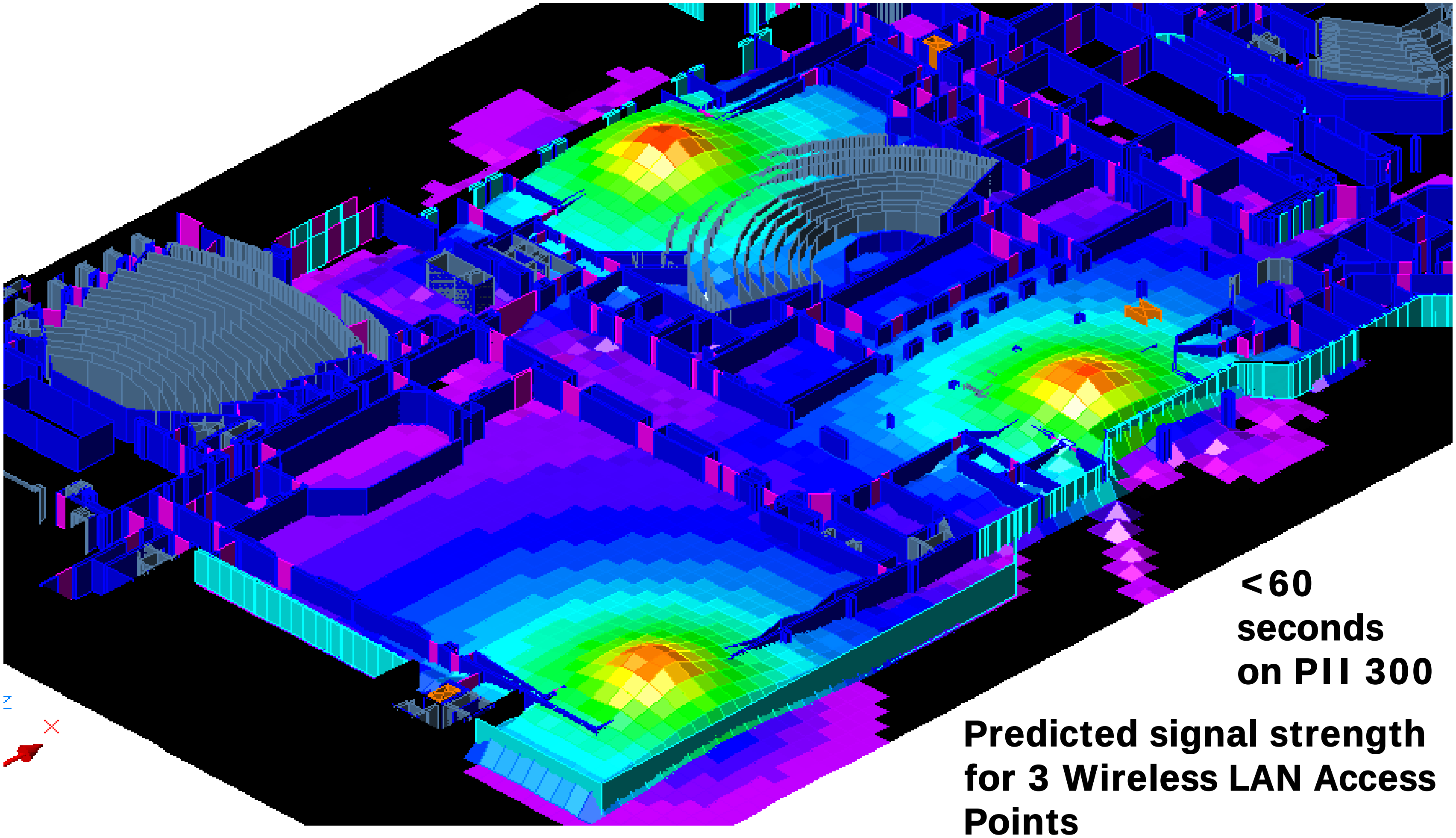
- Technology:
  - IEEE 802.11b, 2.4 GHz DS-SS Wireless LAN
  - 11 Mbps Cabletron RoamAbout access points and modems (Lucent/ORiNOCO OEM)

WLAN Design: 3D Model



10 minutes from CAD file to *SitePlanner* model

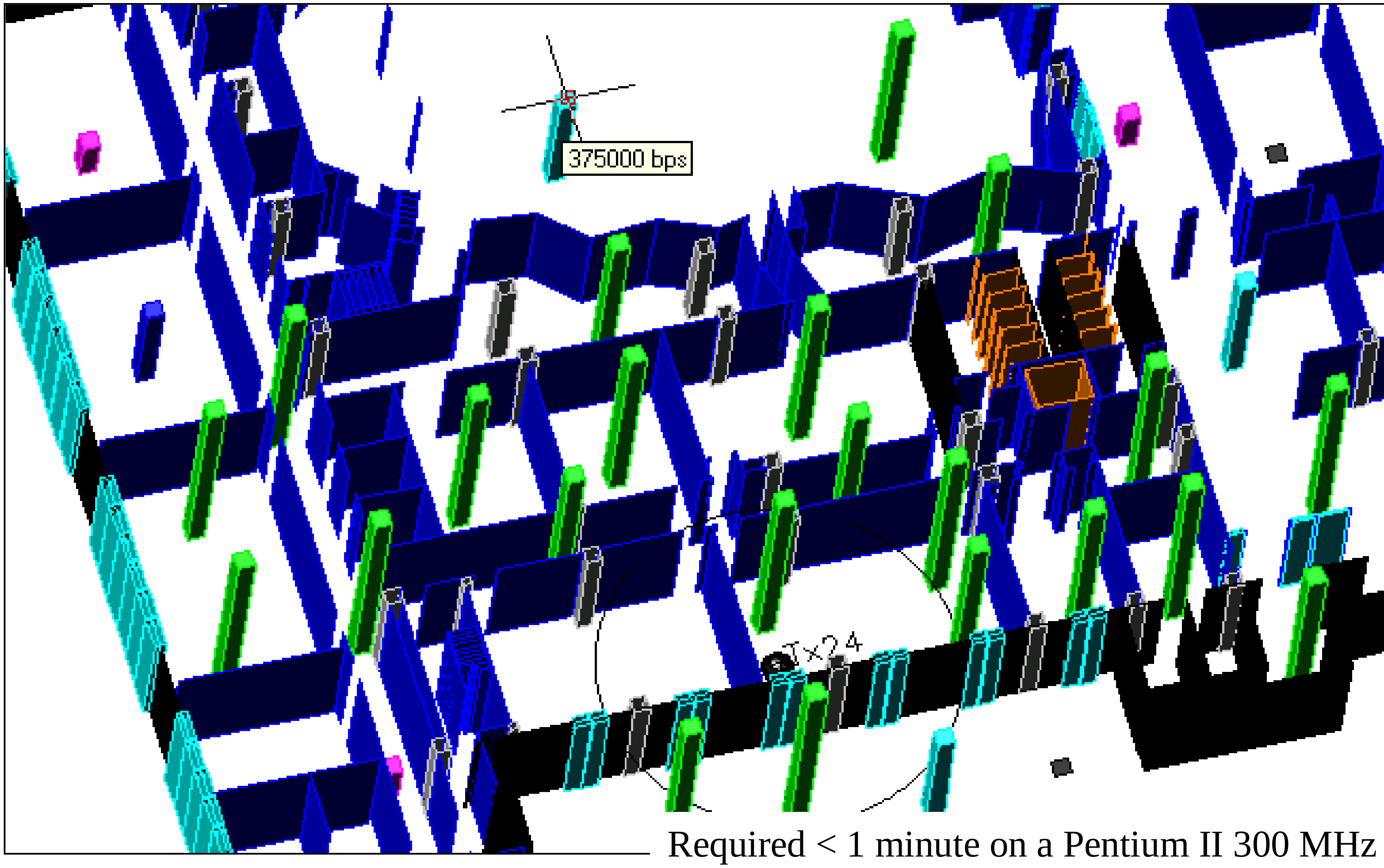
WLAN Design: Predicted Performance



<60 seconds on PII 300

Predicted signal strength for 3 Wireless LAN Access Points

Visualizing WLAN Measurements



Required < 1 minute on a Pentium II 300 MHz PC

Conclusion

- **In-building/campus systems proliferating rapidly**
- **Engineering work load increasing rapidly**
- **Technology cost comparisons vital for deployment efficiencies**
- **Visual and textual records required for common procedures and shared strategies, archiving**
- **802.11a/b/g will require rapid and accurate deployment and maintenance methodologies**
- ***SitePlanner®* facilitates cost and time savings for rapid deployment and ongoing maintenance for any in-building or campus system**