Enabling Technologies for Ubiquitous Personal Area Networks

NSERC Strategic Project Grant 257684

A Summary of Research Activities Involving

Propagation and Channel Modelling

Prof. David G. Michelson

University of British Columbia

Department of Electrical and Computer Engineering

davem@ece.ubc.ca

11 December 2003

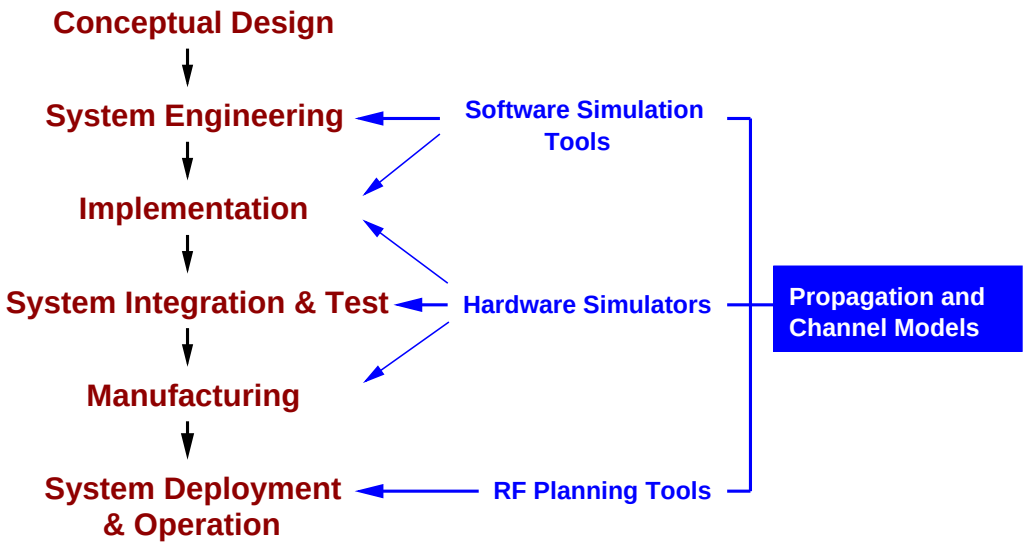
Of all the research activities related to mobile radio that have taken place over the years, those involving characterisation and modelling of the radio propagation channel are among the most important and fundamental.

J.D.Parsons, 1992

The Role of Propagation Modelling

- Propagation and channel impairments constrain our ability to achieve the desired coverage, capacity, and quality of service at a reasonable cost.
- Propagation and channel models translate our knowledge and understanding of the propagation environment into a form useful in the analysis and design of systems.
- Effective models help designers make good decisions and avoid unpleasant surprises.

Propagation Modelling in System Design



IEEE 802.15 - Working Group for WPANs

A variety of short-range wireless networks with ranges up to 10 metres:

- Task Group 1 – Lower Transport Layers compliant with Bluetooth 1.1
- Task Group 1a – Lower Transport Layers compliant with Bluetooth 1.2
- Task Group 2 – WPAN/WLAN Coexistence
- Task Group 3 – High Rate WPAN
- Task Group 3a – High Rate WPAN Alternative PHY
- Task Group 4 – Low Rate WPAN compliant with ZigBee
- Study Group 4a – Low Rate WPAN Alternative PHY

Assessment of Alternative PHY and NET Proposals

- Propagation and Channel Models are key to assessing the strengths and limitations of alternative PHY proposals. Performance metrics include:
  - range
  - performance
  - reliability
- Propagation and Channel Models will play an increasingly important role in assessing the strengths and limitations of alternative networking and routing protocols. Performance metrics include:
  - throughput
  - latency
  - energy consumption

Propagation and Channel Modelling for WPANs

- Traditional approaches to propagation and channel modelling must be modified before they can be applied to WPANs.
- Usage models are key to developing useful propagation and channel models.
- For low rate applications, shadowing and temporal variability are particularly significant.
- For high rate applications, structure and time variation of the delay spread are particularly significant.
- For applications involving large numbers of nodes, contention and interference are critical.

Undergraduate Student Contributors - Phase I

- Shadow Fading in Body Area Networks – *Vanessa Luks and Kelvin Lau*
- WPAN Usage Models and Pathloss in Automotive Environments – *Haynes Cheng, Andrew Tercjak, Benjamin Cheung, and Eric Lai*
- Structure of ns2's Propagation Module – *Johnson Tsai*
- Assessment of Narrowband K-factor in Personal Area Networks – *Ni Xin, Scott Tsai, Cliff Chen*
- Narrowband Diversity Receiver System for Channel Modelling Applications - *Eric Lai*
- WPAN Applications in Automotive Environments – *Haynes Cheng, Alvin Lam, Eugene Lau, Jason Lee*

Graduate Student Contributors - Phase I

- Measurement-based Modelling of Space Diversity in WPAN/WLAN Applications – *Chengyu Wang (MASc Candidate)*
- Estimation of the Propagation Performance Envelope – *Jessie Liu with Chris Hynes (MASc Candidates)*
- Measurement-based Wideband Channel Modelling for WPAN Applications – *Jin Ng (Nokia Vancouver, EECE 571P student)*
- Simulation of Radiowave Propagation in Automotive Environments – *Nima Mahanfar (PhD Candidate - IRCOM, Limoges, France)*

Industrial Collaborators

- Creo
- Intrinsyc Software
- Spirent Communications
- Empowered Networks
- Nokia Mobile Phones
- BCIT Automotive Shop
- General Motors (through PACE)
- SFU Mobile Communications Lab

Propagation Models for ns2

Johnson Tsai (EECE 496 student)

- Ns2 is a widely used discrete event network simulator that provides substantial support for simulation of TCP, routing, and multicast protocols over wired and wireless (local and satellite) networks.
- Propagation models supported by current version of ns2 are extremely limited: free space, two-ray, and lognormal shadowing.
- In summer 2003, Johnson Tsai conducted a detailed survey of the code and documented the interface between the propagation module and the rest of ns2.
- we can now develop a plug-in replacement for the ns2 standard propagation library that incorporates the results of our research during the next two years

Modelling Space and/or Polarization Diversity in WPAN/WLAN Applications

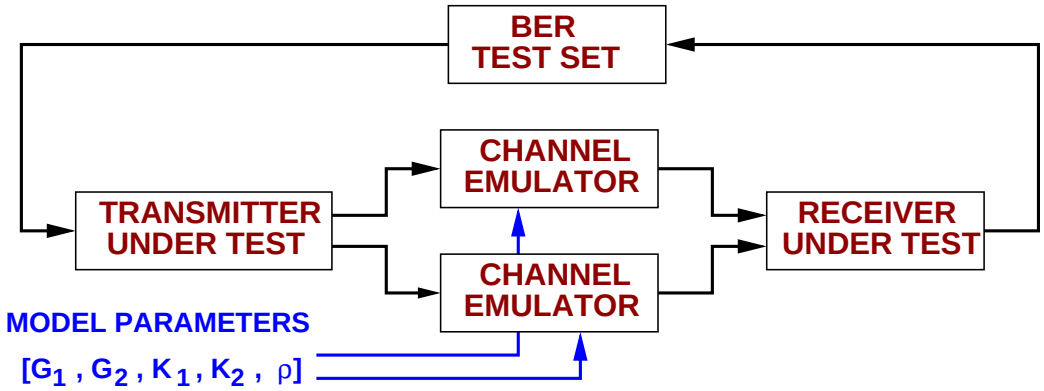
Chengyu Wang (MASc Candidate)

- WPAN/WLAN access points are generally equipped with space diversity antennas to improve performance in fading environments.
- Little data to support the actual performance improvement obtained or how this varies with the type of environment.
- Urgent need to characterize the performance of space and/or polarization diversity performance in different WPAN/WLAN environments.
- More on this later this afternoon.

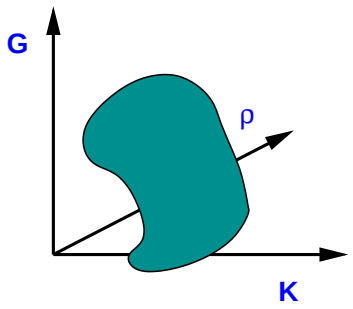
Evaluation of the Propagation Performance Envelope

Jessie Liu (MASc Candidate) with contributions by Chris Hynes

- Propagation model parameters can be applied to a channel emulator for evaluation of hardware performance.



- Problem: Not realistic to treat each parameter independently.
- Solution: Employ bisection strategy to determine the envelope over which system meets performance specification.



- Can use either a reduced channel state vector $\mathbf{D} = [G_{ave}, K, \rho]$ or (preferably) the complete five-element state vector,

$$\mathbf{D} = [G_{ave\,1}, G_{ave\,2}, K_1, K_2, \rho].$$

Characterization of the Wideband Channel Using a Vector Signal Analyzer

Jin Ng (Nokia Vancouver, EECE 571P student)

- Vector network analyzers are traditionally used to characterize the time-varying frequency response of wideband channels in indoor environments.
- Long lengths of coaxial cable and adapters can introduce measurement errors that are difficult to estimate and correct.
- An alternative method of measuring the response of wideband channels involves transmitting a pseudorandom signal with wideband frequency content $X(j\omega)$, measuring the complex received signal $Y(j\omega)$ using a vector signal analyzer, then estimating the frequency response of the channel $H(j\omega) = Y(j\omega)/X(j\omega)$.

- Relative strengths and limitations of VSA-based and VNA-based schemes are not yet well understood, especially constraints on random signal and link budget.

Going Forward

- Complete development of WPAN usage models.
- Complete method for modelling shadow fading and link reliability in WPAN environments.
- Continue measurement-based modelling of narrowband diversity reception in both conventional and non-conventional WPAN environments.
- Continue measurement-based modelling of wideband reception in both conventional and non-conventional WPAN environments.
- Continue development of methods for determining the propagation performance envelope of transceiver hardware.
- Begin numerical modelling study of propagation in vehicular environments.