Effects of Radio Channel on Networking Performance

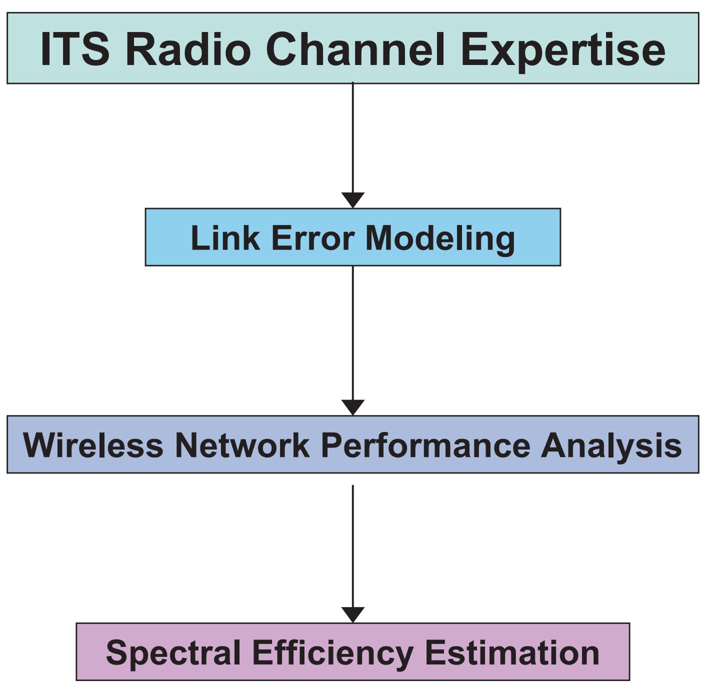
Outputs

- Models of bit, frame, and packet error random processes.
- Quantitative analysis of effects of radio channel on network performance.
- Estimation of the impact the radio channel has on spectral capacity.

The Institute is a recognized leader in radio channel measurement, modeling, and analysis. In the past 10 years this leadership has included work in characterizing multipath in personal communications services (PCS) and wireless local area network (WLAN) frequency bands as well as man-made noise at VHF and UHF frequencies. Such knowledge is essential for the development of robust mobile radio links. For example, development of new adaptive equalizers for modern, wide-bandwidth mobile radio links would not be possible without radio channel multipath measurement, modeling, and analysis.

Wireless network hosts that access the Internet are proliferating. IEEE 802.11 “Wi-Fi” WLAN and 2.5/3rd generation PCS general packet radio service (GPRS) are but two examples. Recent research has shown that the radio channel can significantly degrade performance of the network measured in terms of decreased throughput, increased delay, and lost packets. This degradation ultimately limits the usefulness of allocated spectrum.

The Institute is currently striving to translate its radio channel expertise into information that helps designers analyze performance and regulators estimate spectral efficiency of wireless networks. This is being accomplished by focusing on three tasks: (1) accurate modeling of the link error random process resulting from radio channel impairments, (2) investigation of analytic techniques that correlate network performance to radio channel characteristics, and (3) the computation of wireless network spectral capacities which take radio channel impairments into account (see figure below).



ITS is striving to translate its radio channel expertise into information that helps designers analyze performance and regulators estimate spectral efficiency of wireless networks.

Previous work included development of a radio link simulator incorporating multipath radio channel impairments and the analysis of bit and frame errors generated by the simulator. This work found that bit and frame errors due to frequency selective multipath had independent, geometrically distributed time intervals. This work is significant because it justifies the use of interval simulation which greatly reduces the computational burden of network simulations. In the past fiscal year we have focused on the statistical analysis of a commonly used radio channel random process, the Rayleigh fading process, in order to better understand statistical characteristics discovered through simulation.

It has been proposed that first-order Markov channel models can be used to adequately predict the behavior of a mobile “Rayleigh” fading channel and hence improve the reliability of mobile radio links. Previous research has addressed this question by applying information theory to the amplitude statistics of a stationary mobile radio channel. This approach required numerical analysis to show that for a particular covariance function and range of relevant parameters (i.e., Doppler frequency, symbol period), the channel is approximately first-order Markov. In our analysis, both amplitude and phase information are used to obtain analytic expressions that can easily be used to determine if a non-stationary arbitrary Rayleigh channel is necessarily first-order Markovian. The analytic results are given in terms of arbitrary covariance functions that can readily be applied to measurements. In particular, our results show that the Rayleigh fading channel is not first-order Markovian. In FY 2004, ITS plans to investigate the impact of this finding on characteristics of the link error processes used in network analysis and simulation.

Also, in the past fiscal year, ITS completed a comprehensive search of professional literature which defines the scope of the effects of the radio channel on network tasks. This search indicated that queuing, routing, and end-to-end transmission tasks were the most severely compromised by the effects of the radio channel. Review of research for two of the tasks, queuing and end-to-end retransmission, pointed to the need for more accurate channel modeling which included the higher-order statistical characterization of bit and frame error processes such as their correlation properties and corresponding power spectral densities.

For example, research into the effects of the radio channel on queuing used power spectral density analysis methods of the queuing process. This analysis is dependent on accurate modeling of the traffic, channel, and server random processes. Spectral analysis showed that queues could absorb rapid channel effects such as fluctuations of signal amplitude due to multipath fading but could not accommodate slower channel effects due to shadowing by a wall, building, or feature of the terrain. Queues overflowed and packets were lost when the power spectral density of the bit or frame error process had high low-frequency energy densities.

Similarly research into the effects of the radio channel on end-to-end retransmission showed that retransmission was beneficial, provided that the sender waited for channel conditions to improve. Two types of channel correlation properties are needed to analyze this: first, the correlation of the bit error process to determine when a link may be preventing end-to-end transmission, and second, the correlation of the radio channel to determine appropriate retransmission time-out thresholds. Research is quick to point out that the intimate relationship between end-to-end retransmission and network congestion control procedures, which assume any retransmission is due to congested switch queues, complicates this issue further.

At this time there is a limited set of analytic solutions that correlate the effect of a radio channel characteristic (such as Doppler frequency) on a networking task (such as queuing) through some network performance measure (such as throughput) for small networks. In FY 2004 these solutions will be evaluated to determine their usefulness in translating ITS radio channel measurements to network performance measures for analysis of queuing, routing, and end-to-end transmission methods.

For more information, contact:
Robert J. Achatz
(303) 497-3498
e-mail rachatz@its.bldrdoc.gov