Poster Abstract: PRK-Based Scheduling for Predictable Link Reliability in Wireless Networked Sensing and Control

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Despite decades of research on interference-oriented channel access scheduling, most existing literature are either based on the physical interference model or the protocol interference model, neither of which is a good foundation for distributed interference control in the presence of uncertainties [2]. To address the issue, Che et al. [2] have identified the *physical-ratio-K (PRK) interference model that integrates the protocol model's locality with the physical model's high-fidelity*. Given a transmission from a node S to another node R, a concurrent transmitter C is regarded as not interfering with the reception at R in the PRK model if and only if $P(C,R) < \frac{P(S,R)}{K_{S,R,T_{S,R}}}$, where $P(C,R)$ and $P(S,R)$ is the strength of signals reaching R from C and S respectively, $K_{S,R,T_{S,R}}$ is the minimum real number chosen such that, in the presence of interference from all concurrent transmitters, the probability for R to successfully receive packets from S is no less than the minimum link reliability $T_{S,R}$ required by applications (e.g., control algorithms).

Unlike the physical model, the PRK model is *local* and suitable for distributed protocol design and implementation: 1) The parameters of the PRK model are either locally measurable (i.e., for link reliability and signal strength between close-by nodes) or locally controllable (i.e., for $K(S, R, T_{S,R})$ of each link (S, R)), thus PRK-based scheduling does not need to rely on parameters such as nodes' locations or channel path loss between far-away nodes which are often used in physical-model-based scheduling but are difficult to obtain precisely, especially in a distributed manner; 2) Only pairwise interference relations between close-by nodes need to be defined in the PRK model, thus PRK-based scheduling does not require explicit global coordination which is often used in physical-model-based scheduling. Unlike the protocol model, the PRK model is *of high-fidelity* because it captures the properties of wireless communication (including cumulative interference, anisotropy, and asymmetry) by ensuring the required link reliability in scheduling and by using signal strength instead of geographic distance in model formulation.

To enable distributed scheduling with predictable performance, we design the PRK-based scheduling protocol *PRKS*. In PRKS, we model the problem of identifying the PRK model parameter $K_{S,R,T_{S,R}}$ as a minimum-variance regulation control problem, and we design distributed controllers that allow each link to adapt its PRK model parameter for ensuring the desired link reliability through purely local coordination. For ensuring that nodes interfering with one another do not transmit concurrently, we propose the concept of local signal map that allows nodes close-by to maintain the wireless path loss among themselves; together with the PRK model and transmission power control in protocol signaling, local signal maps enable nodes to precisely identify the interference relations among themselves despite anisotropic, asymmetric wireless communication and large interference range. To address the inherent delay in protocol signaling and to avoid interference between protocol signaling and data transmissions, PRKS uses a control channel for protocol signaling and a separate data channel for data transmissions in a TDMA fashion. With the above mechanisms, PRKS precisely identifies and then avoids interfering concurrent transmissions in scheduling; accordingly, PRKS eliminates the hidden terminal issue which has been a basic challenge in interference-oriented channel access control since 1975.

Through extensive experimental analysis, we observe the following: 1) The distributed controllers enable network-wide convergence to a state where the desired link reliabilities are ensured; 2) Unlike existing scheduling protocols where link reliability can be as low as 2.49%, PRKS enables predictably high link reliability (e.g., 95%) in different network and environmental conditions without a priori knowledge of these conditions; 3) Through local, distributed coordination, PRKS achieves a throughput very close to what is enabled by the state-of-the-art centralized scheduler iOrder [1] while ensuring the required link reliability.

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1. REFERENCES

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