Modelling D2D Communications in Cellular Access Networks via Coupled Processors

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Abstract

Also in cellular networks, D2D communications provide numerous advantages. Nevertheless, modelling D2D systems remains a complex and unsolved task. In this work, we present the first analytical study on D2D system performance. Our approach models interdependencies among D2D and cellular transmitters in details and achieves a conservative estimation of the stability region of D2D systems, as well as evaluates the effects of D2D transmissions on cellular users. Furthermore, the proposed approach can easily trade-off performances for less complexity in a realistic application, i.e., in a proportional fairness optimization.

D2D transmissions, interesting but challenging

We study the D2D in-band underlay scheduling case, where cellular and D2D transmitters share the same resources [1]. Transmissions are strongly coupled each other by mutual interference.

A model to evaluate D2D performance is missing

Goals:
• optimizations of D2D operations;
• efficient coexistence of cellular and D2D users.

Previous work:
• D2D system are evaluated by simulations, assuming the system in saturation, i.e., all transmitters have always traffic to transmit;
• and assuming simple and underperforming scheduling.

What’s missing:
• full knowledge of D2D achievable rates (stability region);
• performance bounds.

System Model and Analysis

We model the D2D system through a queueing system with Coupled Processors (CP) [2].

In D2D, interferences (and throughputs) are univocally determined by the set of simultaneous transmitters.

With CP, the service rate of queues is univocally determined by the set of active queues.

Our method: untangle the net of interdependencies. Model interdependencies through feed forward networks [3].

• CP queues are mapped onto GPS nodes (same arrivals);
• when active, GPS nodes propagate traffic to following nodes, absorbing capacity;
• at each epoch \( t \), GPS nodes serve traffic at slower rate than the corresponding CP node (conservative);
• one network per sorting.

Reducing the complexity: Proportional Fairness

The CP analysis can be simplified depending on the goal.

Optimization can be performed on a small set of sortings carefully chosen:
• Exploiting stability region fairness improves considerably

Numerical Evaluation

Stability region evaluation: Analytical vs. Packet-Level Simulation

Analytical results model accurately the D2D stability region. Model slightly underestimates cellular throughputs (Max. diff: 11.18%).

References