Coding for Super Dense Networks

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Motivations

Problem 1: By the year 2020, more than 50 billion devices will be connected to the networks [1], forming *super dense networks.*

Problem 2: High complexity of fixed transmission scheduling in multiway relay networks.

Problem 3: Low throughput of random access technology. Number of time slots must be more than number of users.

Ideas

Idea 1: Multiway relay network (mRN) is one of prospective solution for future networks, where massive number of users need connections. The mRN has capability of serving multiple users [2].

Idea 2: Uncoordinated transmission is the most feasible scheme for serving massive number of users.

Idea 3: Graph based successive interference cancellation (SIC) [3] combined with iterative demapping (IDM) [4] algorithm is proposed to increase the throughput of the systems.

Prospective Applications

Networks for devastated areas, networks for high dense areas, wireless sensor networks, satellite communication systems.

Conclusions

- We have proposed uncoordinated multiway relaying systems that can serve massive number of users.
- Employment of IDM as the multiuser detector increases the throughput of the systems significantly. It make possible to use number of slots less than number of users.
- The proposed systems can be optimized by choosing a proper degree distribution of u nodes such that G^* close to the bound.

References

[1] Ericsson, "More than 50 billion connected devices," in *Ericsson White Paper*, 2011.

[2] D. Gunduz, A. Yener, A. Goldsmith, and H. Poor, "The multiway relay channel," *Information Theory, IEEE Transactions on*, vol. 59, no. 1, pp. 51–63, Jan 2013.

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[4] K. Anwar and T. Matsumoto, "Three-way relaying systems using iterative spatial demapping," in *ISTC2012*, Aug 2012, pp. 96–100.

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System Model

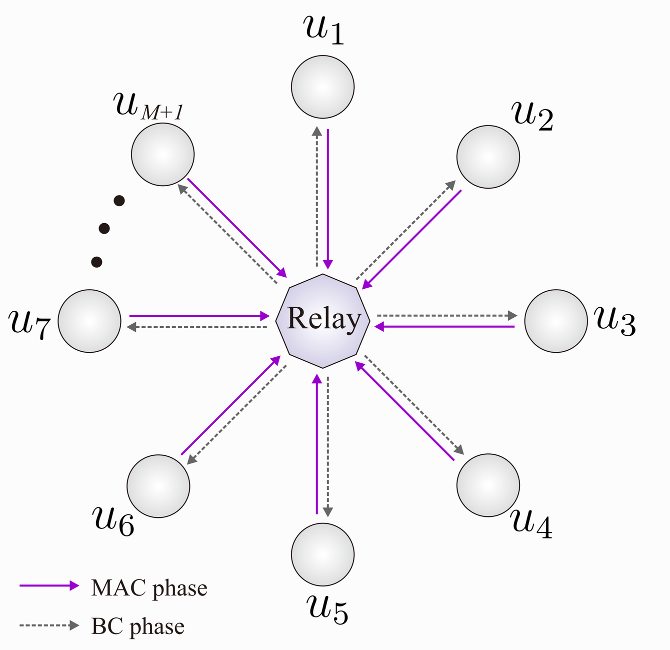

Fig. 1. Multiway relay network

- $M+1$ users want to exchange information among themselves with the help of the relay (Amplify-and-Forward, Half-Duplex).
- *Pair-of-Time-Slot* (PTS): a MAC phase followed by a BC phase.
- 1 *contention period* is composed of N PTSs.
- Offered traffic (logical) load delivered to **one user** :

$$G = \frac{M}{N}.$$

The users randomly select the code type $c_h \sim (h, 1)$ according to the given probability mass function $\Lambda = \{\Lambda_2, \Lambda_3, ..., \Lambda_n\}$, where $\sum_h \Lambda_h = 1$. Networks Rate per user is defined as $R_N = \frac{1}{\sum \Lambda_h h} = \frac{1}{\overline{n}}$, where $\overline{n}$ is the expected length of the code.

Decoding Scheme and Asymptotic Analysis

The system can be represented by a bipartite graph consists of set of u and s nodes. Decoding is performed iteratively between local decoding in u and s nodes. By letting $\{M, N\} \to \infty$, the degree distributions of u and s nodes are respectively defined by

$$\Lambda(x) = \sum_{h=2}^{n_c} \Lambda_h x^h, \quad \lambda(x) = \frac{\Lambda'(x)}{\Lambda(1)} = \sum_{h=2}^{n_c} \lambda_h x^h$$

$$\Psi(x) = \rho(x) = \exp\left(-\frac{G}{R_N}(1-x)\right)$$

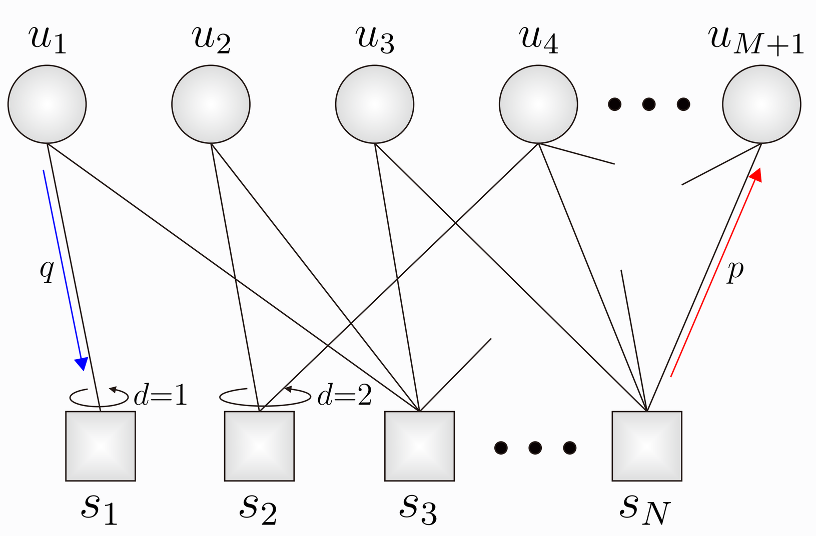

Fig. 2. Bipartite graph

The erasure probability from u nodes to s nodes, and from s nodes to u nodes, respectively are:

$$q = \sum_{h=2}^{n} \lambda_h p^{h-1} := f_u(p) \qquad p = 1 - \left(1 + q\frac{G}{R_N}\right) e^{-q\frac{G}{R_N}} := f_s(q)$$

The above erasure function are plotted into EXIT chart to characterize the decoding convergence behavior. EXIT area theorem are utilized to derive the bound of the system. It is given by

$$R_N + \left(1 + \frac{2R_N}{G}\right) e^{-G/R_N} - \frac{2R_N}{G} < 0$$

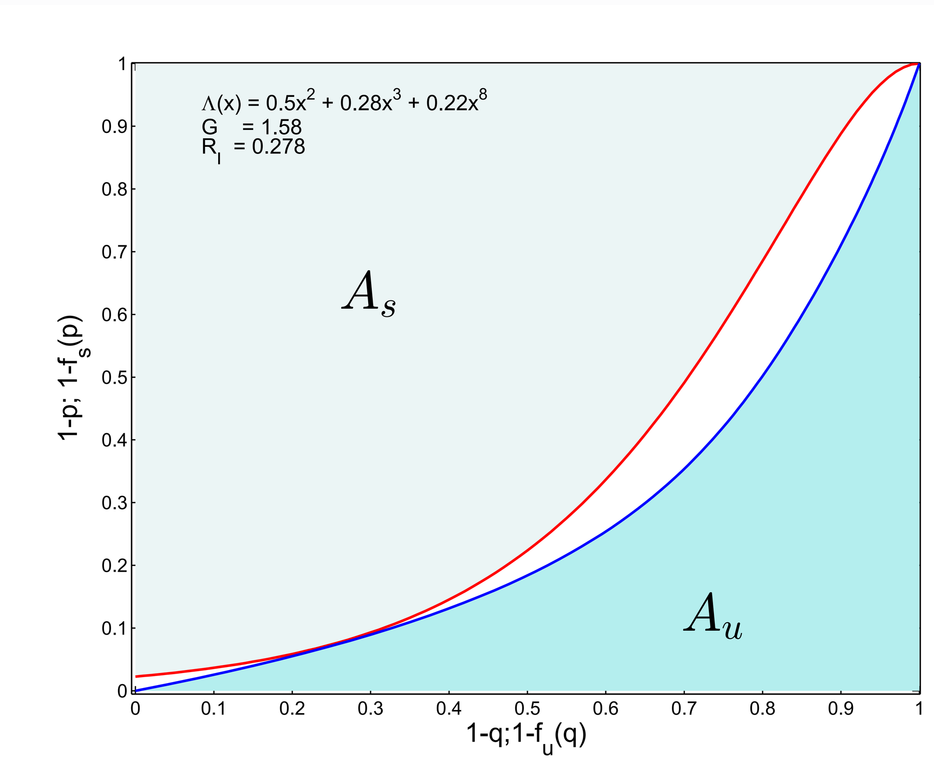

Fig. 3. EXIT Chart example

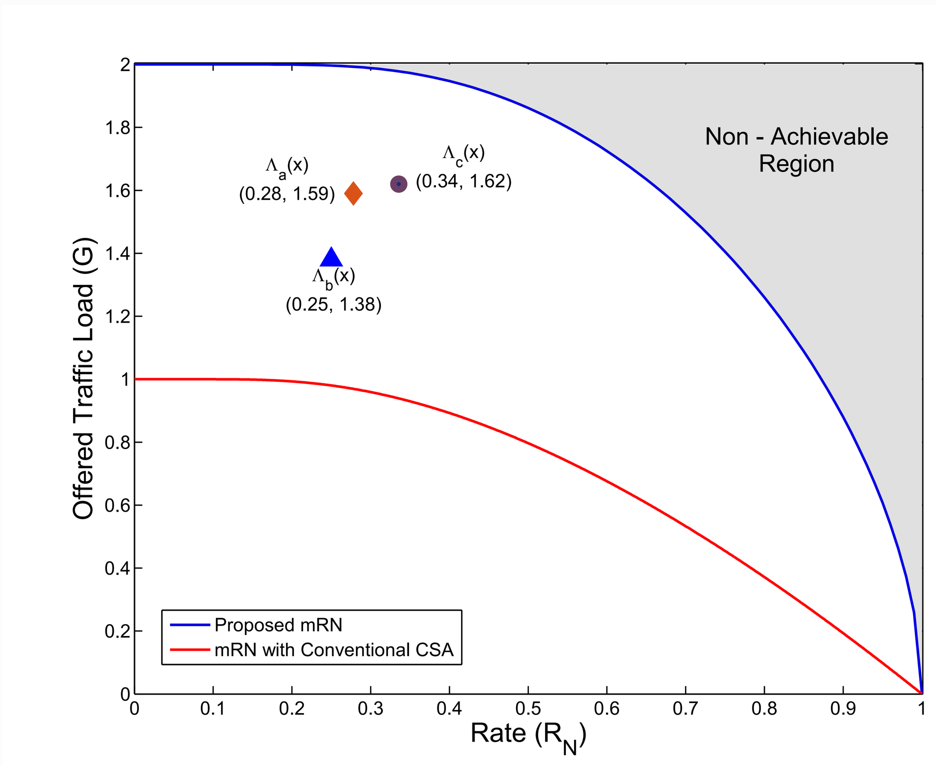

Fig. 4. Bound of the systems

Numerical Results

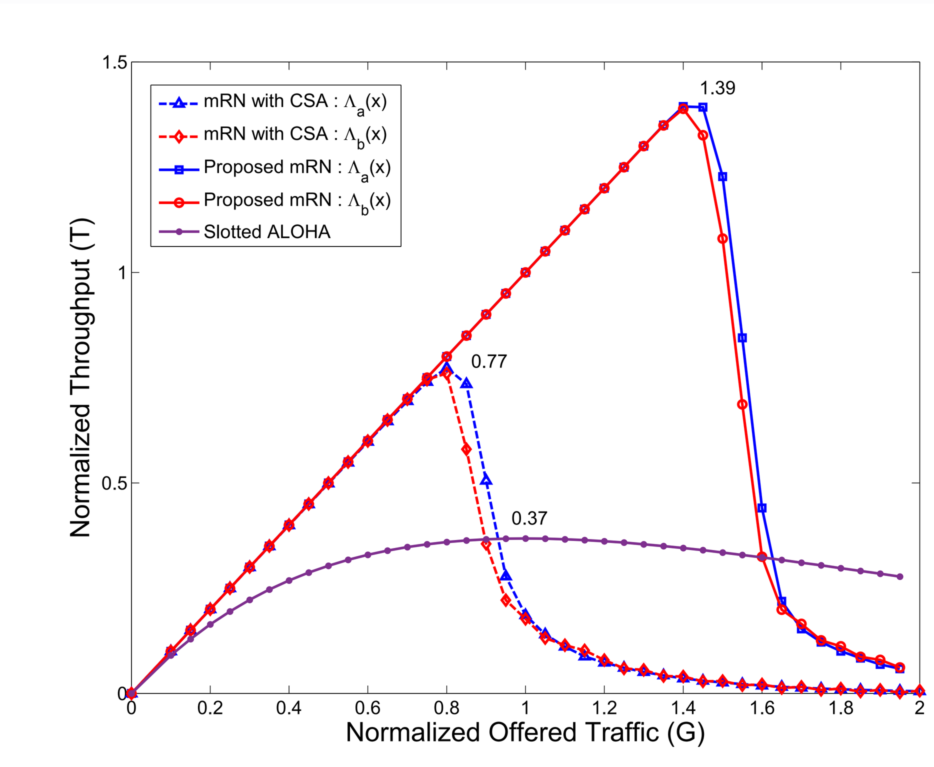

Fig. 5. Average throughput of the systems

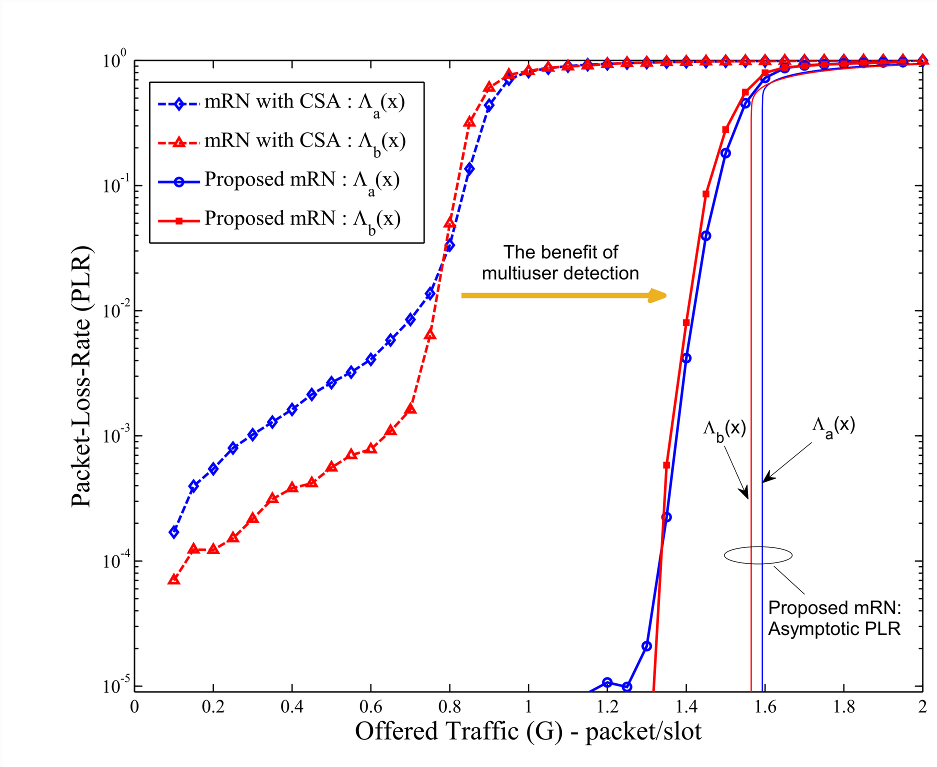

Fig. 6. Packet-loss-rate (PLR) of the systems

The results show that the proposed mRN works very well even though number of time slots is less than number of users. The proposed mRN outperforms the conventional systems employing coded slotted ALOHA (CSA) [3].