# Joint Design of Coding, Modulation and User-Cooperation for Efficient Wireless Communications

**Dr Soon Xin Ng (Michael)**

**Associate Professor in Telecommunications**
Southampton Wireless Group
School of Electronic and Computer Science
University of Southampton
UK

UNIVERSITY OF Southampton

# Background and Motivations

## Internet of Things in 2020

- **35 Billions** things will be connected to the internet.
- **4 times** devices than the population of the whole world.

## Important Questions

- Where do we find the bandwidth and battery power?
- How to create an efficient communications system?

# Channel Coding

- Shannon's communication theory [1] states that reliable communications can be achieved whenever the transmission rate is lower than the channel capacity.
- Turbo codes [2], LDPC codes [3] are power-efficient channel coding schemes considered in the various standards.

[1] C. E. Shannon, "A mathematical theory of communication," Bell System Technical Journal, pp. 379–427, 1948.

[2] C. Berrou and A. Glavieux and P. Thitimajshima, "Near Shannon limit error-correcting coding and decoding: Turbo codes," in Proceedings of the International Conference on Communications, (Geneva, Switzerland), pp. 1064–1070, May 1993.

[3] Robert G. Gallager, "Low Density Parity Check Codes", monograph, M.I.T. press 1963.

# Coded Modulation

- Jointly optimized coding and modulation schemes (TCM, BICM) [4] are bandwidth-efficient schemes.
- Turbo-Coded Modulation [5] and Turbo-Trellis Coded Modulation (TTCM) [4,6] are both power- and bandwidth-efficient.


[4] L. Hanzo, T.H. Liew, B.L. Yeap, R.Y.S. Tee and S. X. Ng, "Turbo Coding, Turbo Equalisation and Space-Time Coding: EXIT-Chart-Aided Near-Capacity Designs for Wireless Channels, 2nd Edition", New York, USA: John Wiley, IEEE Press, March, 2011.

[5] T. M. Duman and M. Salehi, "Performance bounds for turbo-coded modulation systems," in *IEEE Transactions on Communications*, vol. 47, no. 4, pp. 511-521, Apr 1999.

[6] P. Robertson and T. Worz, "Bandwidth-efficient turbo trellis-coded modulation using punctured component codes," IEEE Journal on Selected Areas in Communications, vol. 16, pp. 206–218, Feb 1998.

# Cooperative Communications

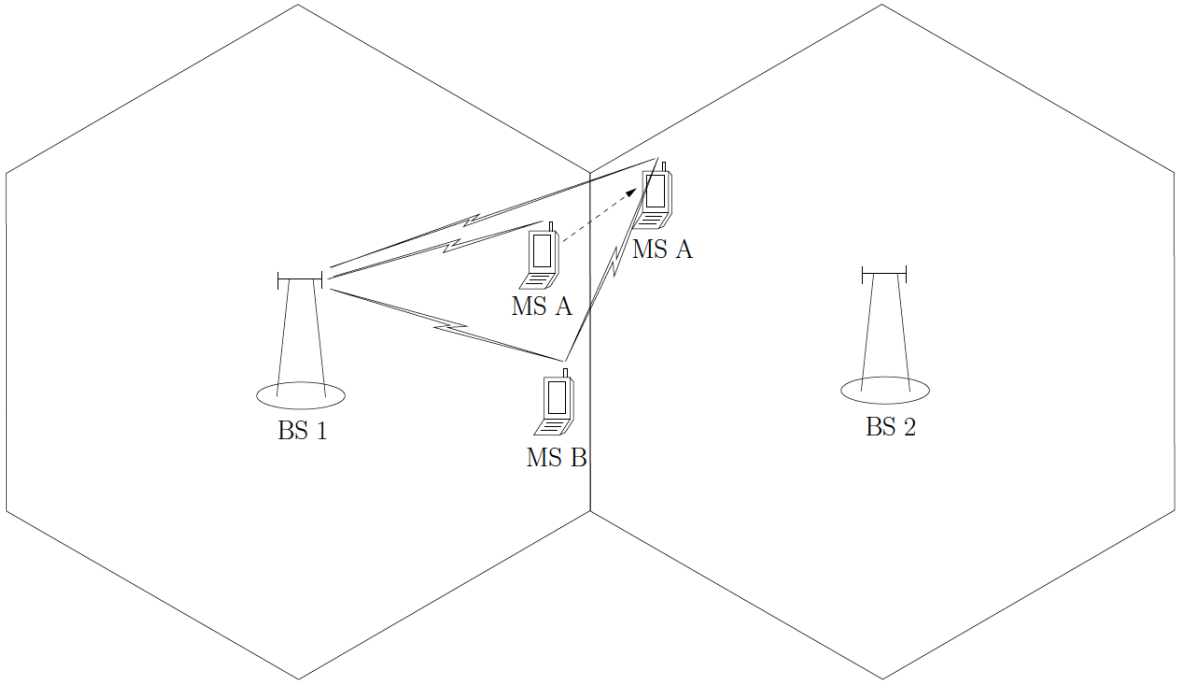
- Multiple-Input Multiple-Output (MIMO) [7] channels exhibit a higher capacity than Single-Input Single-Output (SISO) channels.
- BUT small device: correlation of signals.
- User Cooperation: independent fading and diversity gain [8].

[7] E. Telatar, "Capacity of multi-antenna Gaussian channels," European Transactions on Telecommunication, vol. 10, pp. 585–595, Nov–Dec 1999.

[8] A. Sendonaris, E. Erkip and B. Aazhang, "User cooperation diversity part I: System description," IEEE Transactions on Communications, vol. 51(11), pp. 1927–1938, 2003.

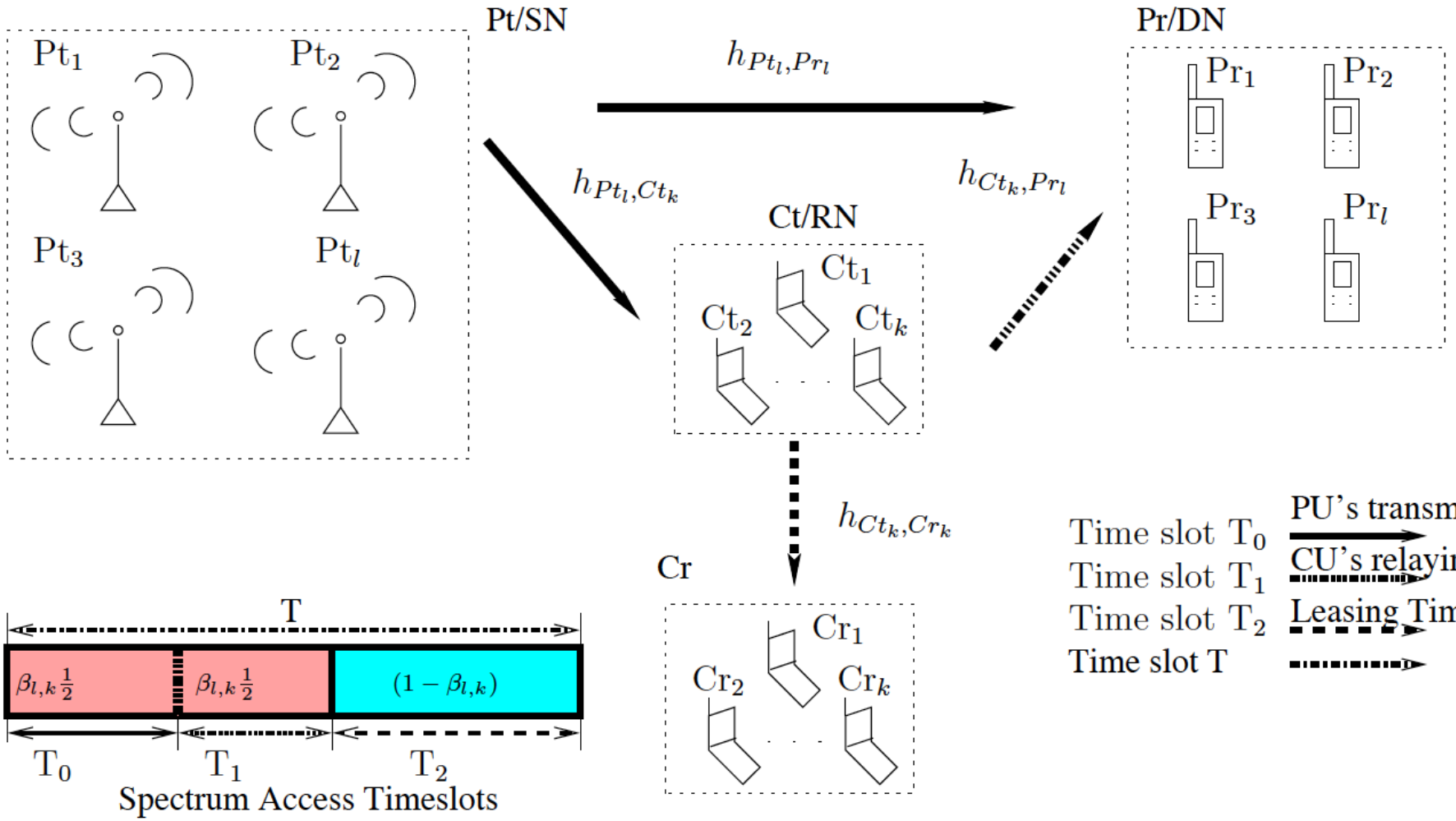
# Cooperative Communications

- Cooperative communications can increase the capacity, transmission reliability, energy efficiency and coverage area of the overall system.




- The LTE-Advanced standard has also considered relaying techniques.

# User Cooperation



# User Cooperation Game

- None cooperative game [9]:

Primary Users (PUs) compete to get the best Cognitive User (CU) to relay their signals.

- Cooperative game [10]:

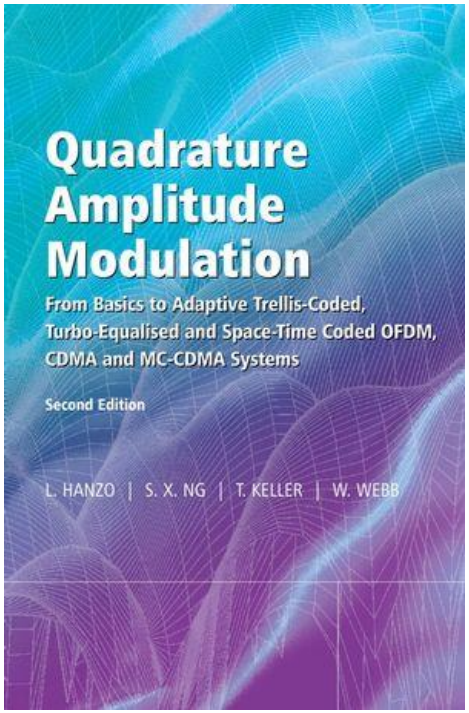
PUs give up any futile competition and cooperatively take turns, one at a time, to access the available CUs.

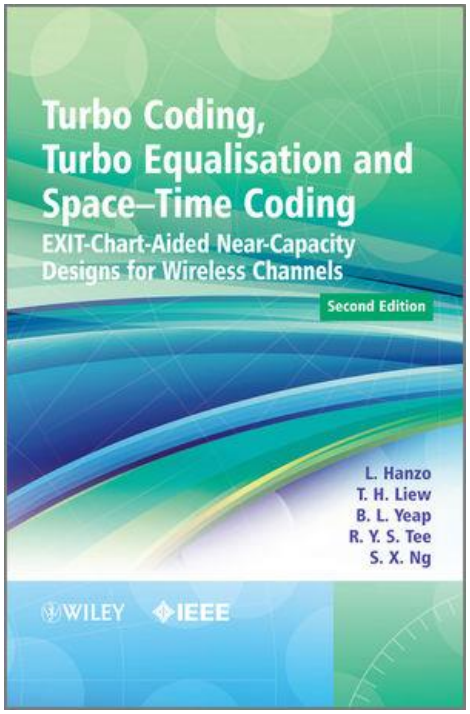
Convergence to an equilibrium is enforced by the threat of limited-period punishment.

[9] S. Bayat and R.H.Y, Louie and Yonghui Li and B.Vucetic, "Cognitive Radio Relay Networks with Multiple Primary and Secondary Users: Distributed Stable Matching Algorithms for Spectrum Access, " IEEE International Conference on Communications (ICC), Page 1-6, June, 2011.

[10] W. Liang, S. X. Ng, J. Feng and L. Hanzo, "Pragmatic Distributed Algorithm for Spectral Access in Cooperative Cognitive Radio Networks", IEEE Transactions on Communications, 2014.

# Thank You.




Our related works can be found from the links below:

http://www.wireless.ecs.soton.ac.uk/res/int/cooperation

http://www-mobile.ecs.soton.ac.uk/newcomms/?q=res/int/cooperation