inside view

Li Chen, Rolando Carrasco and Ian Wassell

FURTHER READING

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'Opportunistic nonorthogonal amplify-and-forward cooperative communications', L. Chen, R. A. Carrasco and I. J. Wassell

Cooperative communication looks very promising as a next-generation wireless network architecture. Li Chen, Rolando Carrasco and Ian Wassell tell us why and how they are working to improve system performance

ABOVE: Dr Li Chen (left) is a lecturer with the School of Information Science and Technology, Sun Yat-sen University in China. His research interests include channel coding, information theory and cooperative communications.
Professor Rolando Carrasco (centre) is an emeritus professor of Newcastle University in the UK and his research interests include channel coding, digital modulation and mobile communications.
Dr Ian Wassell (right) is a senior lecturer with the Computer Laboratory of the University of Cambridge in the UK and his research interests include broadband fixed wireless access, sensor networks and cooperative networks.

A shared approach

In our work we aim to develop cooperative communication technology for application to broadband fixed wireless access systems, which will enable broadband service to be delivered more quickly and reliably. This is a collaborative research project supported by the EPSRC in the UK. Cooperative communications motivates network users to share their resources (such as antenna and processing power) for signal transmission, creating multi-path propagation for the signal and delivering diversity gains to improve system performance. As wireless communication becomes pervasive in modern lives, cooperative communication ignites the transition for the network users from just being 'resources consumers' to also being 'resources providers'.

Applications

As our handsets are becoming smaller but providing more functions, transmission diversity is important to guarantee that our increasingly greedy demands for data can be satisfied. Therefore, one of the main applications of cooperative technology is in the mobile communication industry. For example, it will soon be standardised in the LTE-Advanced system giving the capability of multi-gigabit/sec data rates. In addition, it can also be applied in other areas such as military communications and disaster management in which mobile users can form a wireless ad hoc network and relay each other's signal to different destinations. Other possible applications include cooperative sensing for cognitive radio that can better detect the available transmission spectrum, and co-operative relaying for wireless sensor networks that can reduce the energy consumption of distributed sensor nodes.

Challenges

The application of cooperative communications raises a few key challenges. First of all, cooperative communication requires sophisticated time synchronisation and action coordination between network users. Secondly, cooperating users may hop from one communication cell to another, giving a mobility management issue. Knowledge of channel condition is vital in a cooperative network and this needs to be updated in a timely manner so that the system can provide a seamless handover or even partner switching without affecting its QoS. Thirdly, as cooperating users are involved in processing each other's data, the compromise between system performance and power consumption becomes a challenging issue. This compromise is especially important for applications such as wireless sensor networks. Finally, the interaction between network users also brings up challenges concerning information security. We need to guarantee a secure and yet reliable communication.

Practical limitations

The main factors limiting performance include the physical layer signal processing technologies, such as channel estimation and equalisation, interference cancellation and error-correction. Without solid support from all of them, system performance will be degraded. The other limiting factors are the multiple access technologies. Currently, most of the cooperative systems are designed based on the orthogonal time channels that enables time-division multiple access. However, by allowing the orthogonal frequency channels to be further deployed, the source user and the cooperating users can transmit simultaneously. It exploits more effective use of channel resources and improves system performance. In fact, more fully exploiting the spectral resource is one of the contributions in our Letter. In addition, since more demands will be placed upon users' terminals, it is important to reduce power consumption and also to improve battery technology.

Advancing cooperation

In our Letter, we have proposed an opportunistic nonorthogonal amplify-and-forward (ONAF) cooperative communication system. It is the first time these two important features for enhancing system performance – opportunistic relay selection and nonorthogonal transmission – have been integrated. With the cooperative network evolving to be more intelligent, recent research has shown that opportunistically selecting the best relay for signal re-transmission will achieve the same diversity gain as schemes that require multiple relays for signal re-transmission. More importantly, opportunistic relaying alleviates the challenges concerning user interference and network power consumption. Also, nonorthogonal transmission that allows the source user and the relaying user to transmit simultaneously will enhance the system performance. In this Letter, we have proposed an ONAF system model which we have investigated using both information theoretic analysis and simulation studies. Our simulation results demonstrated that with a transmission rate of 4 bits/s/Hz, at least 2 dB performance gain can be achieved over the existing schemes. This performance gain is more significant for a larger cooperative network, in which there are more relaying candidates. However, such a performance improvement is at the expense of system complexity.

Next steps

This idea can also be applied to other types of cooperative networks, such as the decode-and-forward network, and it is expected to achieve further performance gains. Moreover, we have so far established the advantage of the opportunistic nonorthogonal cooperative system from an information theoretic aspect. To realise the promised performance gain, we need to further investigate the design of suitable error-correction codes to be deployed in the proposed cooperative system.

Research in cooperative communications has been thriving in the last decade providing many useful cooperative protocols and their corresponding signal processing technologies. In the next few years, its application should become widespread. We expect cooperative communications to be standardised and commercialised in the wireless communication market. In the meantime, we also foresee such concepts being deployed in many other areas.

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