Virtual MIMO Based Wireless Communication for Remote Medical Condition Monitoring*

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Abstract. Remote medical monitoring services for elderly people is necessary, especially for societies where the population of elderly people are rapidly increasing and healthcare costs are increasing due to lack of human resources. Wearable health-monitoring systems (WHMSs) can provide real-time medical condition monitoring using multiple biosensors attached to the human body. In this paper, virtual multiple input multiple output (MIMO) is proposed as a suitable technique for biosensor networks as it enables higher throughput capacity and less energy consumption than conventional schemes. The performance analysis of the proposed system shows that the lifetime of the virtual MIMO-based system outperforms existing systems.

1 Introduction

Wearable health-monitoring systems (WHMSs) [1] are representative technologies that offer real-time health condition monitoring and reporting to the user and the user's desired medical center. In WHMSs, multiple biosensors attached to the human body detect physiological signals such as heart rate, blood pressure, body temperature, and oxygen level. Detected signals are transmitted to a medical center through a central node (CN), so the user and the remote medical center can check the user's health condition.

Biosensors for WHMS are equipped with small batteries. For reliable and continuous support, energy-efficient transmission techniques are essential in extending the system's lifetime. Multiple input multiple output (MIMO) transmission ensures lower energy consumption compared to conventional transmission through long-haul wireless communication channels that experience fading conditions. However, MIMO transmission is not appropriate for small wireless sensor network (WSN) devices. In

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the paper, Virtual MIMO (V-MIMO) [2] is proposed to be used for WHMS applications. V-MIMO technology provides an enhanced performance by using the spatial diversity gain of the signals in a fading environment.

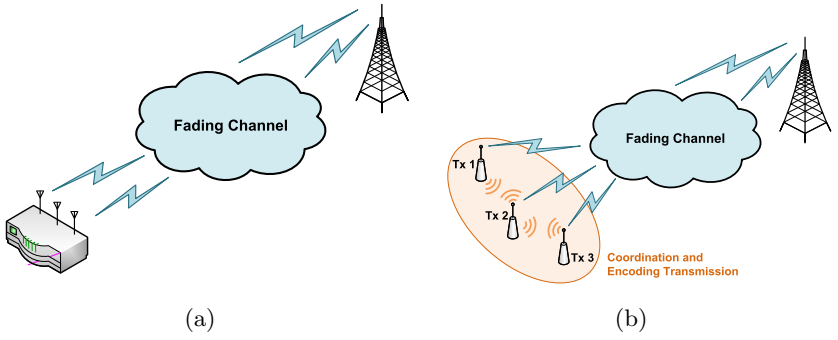


Fig. 1. Concept of MIMO and Virtual MIMO Transmission

This paper is organized as follows. In chapter 2, MIMO and virtual MIMO techniques are explained. In chapter 3, we propose a virtual MIMO-based wireless medical monitoring system and evaluate its performance. Chapter 4 concludes the paper.

2 MIMO and Virtual MIMO Techniques

Fig. 1 shows a general concept diagram of MIMO and Virtual MIMO transmission. MIMO is a transmission technique that uses antenna arrays to obtain diversity gain. Virtual MIMO technique is an alternative solution that realizes cooperative MIMO transmission on WSN devices which each consist of single antennas. As shown in fig. 1 (b), each sensor node acts as an antenna of an entire virtual antenna array. V-MIMO also obtains MIMO diversity gain, which results in minimizing transmission energy. However, compared to MIMO system, V-MIMO requires additional energy consumption due to local data exchange between the CN and sensor nodes.

3 Virtual MIMO-Based Wireless Communication for WHMS

Fig. 2 shows an example of the proposed V-MIMO based medical monitoring system. As shown in fig. 2, V-MIMO use various types of biosensors attached on the human body to monitor the user's health condition. For example, V-MIMO nodes can be a pacemaker, a glucose meter on user's wrist, and an in-shoe sensor such as Nike+ [3]. Health-monitoring data from each biosensor is sent to CN which conducts data collection and processing. After the CN finishes data processing, the processed data is transmitted to a medical center.

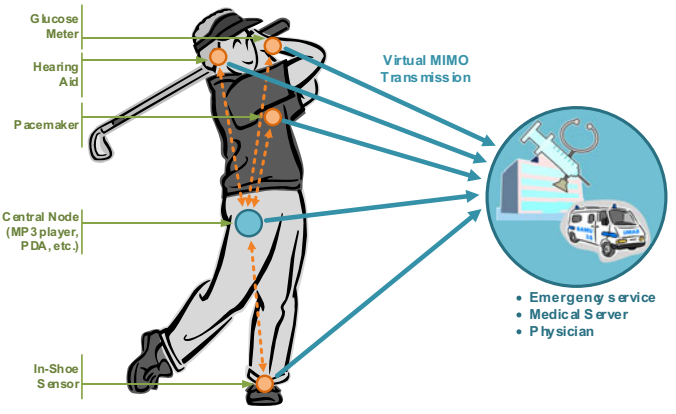


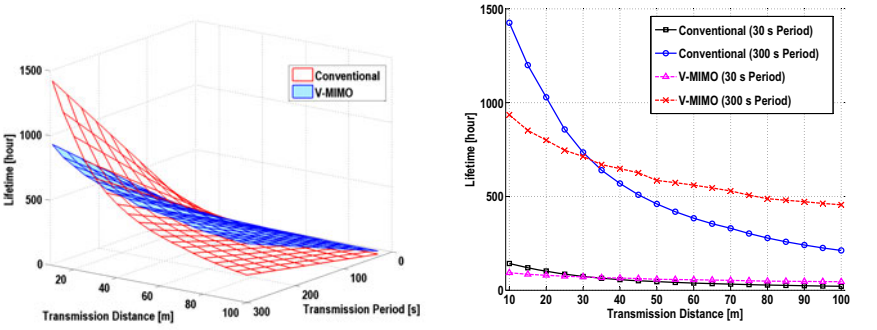
Fig. 2. Virtual MIMO-based wearable health-monitoring system

Biosensor data communication consists of two transmission phases: local transmission and long-haul transmission. First in local transmission, each biosensor sends perceived physiological data with a central node. Then, the CN processes the data and performs space-time block coding (STBC). Afterwards, the coded data is transmitted to the biosensors which take part in V-MIMO transmission. After finishing local transmission, the CN and the biosensor nodes can transmit the coded data simultaneously to a remote medical center, which is commonly a long-haul transmission. In long-haul transmission, not only the CN but also the other biosensors participate so that they form a virtual antenna array to accomplish MIMO diversity gain.

In general, WHMSs regularly report user condition to the medical center. According to user condition changes, however, the report interval can vary. For example, when biosensors detect significant changes in a person's body condition (such as irregular heart rate or blood glucose), the system should begin to send the monitored health data more frequently. In this case, frequent data monitoring and transmission will lead to a more significant energy consumption of each biosensor. To be able to estimate the lifetime of the health monitoring devices, the varying energy consumption rate caused by the transmission interval changes needs to be considered.

Performance analysis of the proposed V-MIMO transmission system is conducted as follows. There are two types of nodes, a central node and a biosensor, at each transmitter and receiver side, which consist of a 2×2 virtual antenna array. For simplicity, it is assumed that all nodes are the same. Each biosensor has single transmission antenna, and is equipped with a lithium coin battery ENERGIZER CR2032 [4] which has a capacity of 480 mWh.

Fig. 3 (a) illustrates the lifetime of WHMS system where 10,000 bits of body information is transmitted periodically. Fig. 3 (b) shows four representative simulation results from Fig. 3 (a). Despite of additional energy consumption for local data exchange, V-MIMO consumes less energy than conventional method for transmission distance longer than 33 m. The effect of energy efficiency improvement from using



(a) Simulation Results (Transmission Periods $0 \sim 300$ s)

(b) Representative results (Transmission Periods 30 and 300 s)

Fig. 3. System Lifetime Comparison (Conventional vs. V-MIMO Transmission)

V-MIMO becomes apparent as the transmission period becomes longer. As a result, we can conclude that V-MIMO transmission is more energy-efficient transmission mechanism which shows significant gain in throughput and power consumption as the transmission distance becomes longer.

4 Conclusion

In this paper, a V-MIMO based wireless communication system for remote wireless medical monitoring is proposed. The results show that V-MIMO transmission can provide large advantages in transmission distance and energy consumption at the cost of additional control to coordinate the individual wireless health monitoring devices.

References

1. Pantelopoulos, A., Bourbakis, N.G.: A Survey on Wearable Sensor-Based Systems for Health Monitoring and Prognosis. IEEE Trans. Sys. Man and Cyber. 40(1), 1–12 (2010)
2. Cui, S., Goldsmith, A.J., Bahai, A.: Energy-Efficiency of MIMO and Cooperative MIMO Techniques in Sensor Networks. IEEE J. Sel. Areas Commun. 22(6), 1089–1098 (2004)
3. Nike+, `http://nikerunning.nike.com`
4. Energizer CR2032 Product Data Sheet, `http://data.energizer.com/PDFs/cr2032.pdf`