RT-WiFi: Real-Time High Speed Communication Protocol for Wireless Control Systems

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Due to their enhanced mobility and reduced configuration and maintenance cost, wireless control systems (WCSs) are widely used in process and vibration control systems, on medical devices, unmanned vehicles and robotics. However, most literatures in WCSs focus on monitoring and low speed control, and less effort has been made on high speed WCSs. It is because most existing wireless communication protocols cannot provide real-time and reliable communication links with preferable high speed by taking energy saving into consideration.

In our current joint project [1], between University of Texas at Austin and University of California, Berkeley, we are building a network-based human rehabilitation system to provide wire-free rehabilitation at local site and bio-feedback and remote mobility for tele-rehabilitation. In this system, sensors, controllers, and actuators are distributed in different locations and connected over high speed wireless networks. In order to achieve real-time motion control, high sampling rate and reliable communication links are critical, which brings great challenges to the wireless protocol design. Fig. 1 demonstrates the result of how sampling rate could affect the performance of a human rehabilitation system. In this simulation, the nominal model of the rehabilitation device in [1] was employed as the controlled plant and a PD (Proportional plus Derivative) controller was implemented. The reference was set as a unit square signal with the frequency of 2 Hz. As shown in Fig. 1, higher sampling rate leads to smaller overshoot and shorter settling time. The result also indicates that a motion control system usually prefers sampling rate higher than 1 kHz to guarantee good tracking performance. However, current commercially available wireless technologies cannot be directly applied to the high speed WCSs. For example, wireless protocols designed for low-power personal area networks including Bluetooth, ZigBee and WirelessHART do not provide sufficient data rate to support sampling rate as high as 1 kHz. On the other hand, although Wi-Fi offers enough data rate, it does not have any timing guarantee on packet delivery and it is not designed to be energy efficient.

To address this problem, in this work we propose Real-Time WiFi (RT-WiFi) which is a real-time high speed wireless communication protocol. At the very bottom, RT-WiFi adopts physical layer of Wi-Fi in order to support high data rate. On top of that, we are hacking MAC (medium access control) layer of Wi-Fi to adopt TDMA (Time Division Multiple Access) for providing real-time data delivery and to support sampling rate as high as 1 kHz. On the other hand, although Wi-Fi offers enough data rate, it does not have any timing guarantee on packet delivery and it is not designed to be energy efficient.

1. REFERENCES