UGC/FDS11/E03/19

Title of Project

English: Energy-efficient joint resource scheduling for wireless networked control systems

Chinese: 無線網絡控制系統中的多資源節能調度問題

Abstract of Research Comprehensible to a non-specialist

Wireless networked control system (WNCS) is a control system wherein the control loops are closed through a wireless network. The defining feature of a WNCS is that different system components (including sensors, actuators, and controllers) exchange the control signals and feedback signals among them in the form of information packages via the wireless network. There are many sensing and control applications like self-driving vehicles, where the environmental data is collected periodically and control decisions are made by the control algorithms and delivered to actuators afterward. These tasks must satisfy the real-time constraints. The sensors and actuators use wireless network to communicate with the controllers, while the controllers use CPU to handle the data and calculate the best decision.

To measure the Quality of Service (QoS) offered by a WNCS, we usually count how many tasks executed satisfy the end-to-end time constraints.

If we take the self-driving vehicle as an example, the typical tasks work as follows: the sensors (including cameras, radars and lasers) first perform the critical function of detecting the dynamic conditions surrounding the vehicle, and send the data to the controllers. The controllers (processors) handle data received from the vehicles' sensors and calculate the best decision. Finally, the decision (control signal) is sent to the actuators which physically perform actions such as changing gears, applying brakes, steering, and so on.

How to schedule these real-time tasks in WNCS to make every task satisfy the time constraints as well as to reduce the energy consumption is a key issue in WNCS. There are two kinds of resources involved: the network resource and the computing resource. Traditional approaches schedule the two resources separately. They either assume that the execution time of the control algorithm is negligible or consider it as a constant. Therefore, most of the previous works only focus on how to model the constraints of transmission conflicts, but do not consider the computation time of the control algorithms while enforcing the end-to-end deadlines.

This motivates us to study the *Joint Resource Scheduling* (JRS) model where two resources are allocated to the tasks, and the three segments of each task have precedence constraints. In this project, we model each real-time task as a three-phase job that consists of three segments: a sensing segment which transmits sensed data to the

controller, a computing segment which computes the control decisions, and an actuating segment which transmits the control signals to the actuators. For each three-phase job, its computing segment cannot start until the sensing segment completes, while the actuating segment cannot start until the computing segment completes. Both sensing and actuating segments are processed on the network resource while the computing segments are executed on the computing resource. If all the three segments have arbitrary processing times, it is hard to get the optimal schedule in polynomial time. However, the processing times of the sensing and actuating segments may have some patterns because the amount of data sent to the controllers from sensors of the same type is the same which implies that these sensing segments have the same processing time. Similar argument goes for actuators with the same type. If the patterns of sensing and actuating segments are known, it is possible to design polynomial time optimal algorithms. Our goal is to decide whether all of these tasks can be scheduled while all the constraints are satisfied. If yes, then we want to find an optimal schedule to complete the tasks as soon as possible. Otherwise, we need to adjust the speed of the processors so that they can calculate faster but then the power consumption will be larger. How to balance the processor speed-up and power consumption is another key objective in our project. The proposed scheduling problem is one of the fundamental problems not only in WNCS, but also in other systems that present similar patterns. Any improvement of the joint scheduling method could increase the utilization rate of the system and therefore improve the system performance.