IJCSN International Journal of Computer Science and Network, Volume 4, Issue 1, February 2015
ISSN (Online) : 2277-5420 www.IJCSN.org
Impact Factor: 0.417

Review- Energy Efficient Data Transmission over Wireless Network for Control System

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Abstract - Transmission energy management is a key issue to optimize the life-time operation of the overall wireless network. However, designing a communication protocol for wireless networked control system brings the additional challenge of guaranteed stability as compared to traditional wireless sensor network. The motivation of this paper is to minimize the energy consumption of the communication system where nodes are operated on batteries. . The total energy consumption includes both the transmission energy and the circuit energy consumption. By using novel algorithm that assigns communication radii to sensors as a function of their load. We show via both analysis and simulation that our algorithm, which utilizes shorter transmission ranges for heavily loaded sensors and larger transmission ranges for lightly loaded sensors, is about 50% more energy efficient than schemes utilizing a fixed transmission radius for every sensor. We also show that our algorithm obtains a 95% improvement as compared to the case of a stationary base station

Keywords - *Minimum energy transmission; optimal schedules; delay; communication protocol.*

1. Introduction

Wireless Networked Control Systems are those distributed system in which sensors, actuator and controllers interconnected through a wireless network. Wireless Networked Control Systems are ever-increasingly used to cover very large scale distributed area including factory automation system, industry automation, home automation systems, building automation, automated highway systems. By using wireless network, all the plant devices (sensors, actuator and controller) are exchange information with one another. The use of wireless network offers many benefits as compared to traditional wired networked such as the ease of installation, cost, scalability, maintenance and low complexity and flexible to implementation and modification in any control application. We consider a wireless network where sensor nodes are operated on limited lifetime of battery. Each node consists of processing capability, battery, radio units and energy harvesting rechargeable transmitter. To optimize the life time operation of the overall wireless network, these sensor nodes are designed to operate as automatically as possible in terms of minimizing energy consumption for many data transmission.

However, designing a WNCS brings the additional challenges of providing the guaranteed stability of the closed loop control system since control systems have urgent requirement on timing and reliability. But the fulfillment of this requirement in wireless sensor network is not possible due to the properties of wireless communication and the limited lifetime of sensor nodes. The wireless communication has unreliability of wireless transmission which will causes non zero packet error and also non zero delay due to shared wireless medium. Decreasing the packet error probability, minimizing transmitted bits, delay and sampling period improves the performance of the control system at the cost of more consumption of energy in the communication. Thus, there is a need for designing a system in which the joint performance of these system including communication parameters and the control parameter can be energy efficient.

The communication system design for Networked Control System has attention in the literature because of lack of efficient optimization of control and communication system. This will led to the simplification of problem as well as providing solution through numerical methods by using less formulation. If there is a collision in a network then we have to retransmit the corrupted packets and it will increase the energy consumption. So by assuming no packet error occurs unless there is collision in the network which will increase energy consumption. The constraints of the problem are the schedulability and maximum transmit power restriction of the communication system and the reliability and delay requirement of the control system to guaranteed stability.

For the sampling period and delay requirement, optimization of the scheduling have to be perform by formulations to minimize the overall performance loss. This formulation cannot be applied to Wireless Network Control System. The communication system design for Wireless Network Control System focus on providing low delay, improve the lifetime of sensor network and reduced network traffic across a very large mesh distributed network. The optimization problem formulations for Wireless Network Control System have other objective to finding the best values of the sampling period and network scheduling parameter. The main objective is to minimize energy consumption of the network which will improve the overall life time of network.

2. Related Work

INRIA Rhˆone-Alpes, CNRS, ACCESS Linnaeus Centre [1] proposes multilayer architecture of networked control system in which there is system in which light of energy is used. Their aim is to develop an energy aware management in wireless communication and control co-design.

Yalcin Sadi, Sinem Coleri Ergen, , and Pangun Park [3] proposes a novel algorithm that assigns communication radii to sensors as a function of their load. Their aim is to minimize the energy for data transmission in wireless communication which wills helps to increase network lifetime.

Husheng Li, Lifeng Lai, and H. Vincent Poor [4] proposes algorithm to solve the optimization problem. This algorithm is used for finding routing modes. Their aim is to minimize the delay for improving the performance of the system.

P. Park, C. Fischione, A. Bonivento, K. Johansson, and A. Sangiovanni-Vincent [2] proposed a novel protocol for control application. The design approach relies on a constrained optimization problem, whereby the objective function is the energy consumption and the constraints are the packet reliability and delay.

W. P. M. H. Heemels, A. R. Teel, N. van de Wouw, and D. Nesic [7] proposed a general framework of networked control system. Which involves communication constraints, varying transmission intervals and varying transmission delays? The result shows that how tradeoffs curves between MATI and MAD can be computed providing designers of NCS with proper tools to support their design choices.

Wanshi Chen, Michael J. Neely, Urbashi Mitra [5] proposed explicitly derive the optimal offline scheduling algorithm for the individual delay constraint model under dynamic arrivals and static channels. Their aim is to achieve comparable energy performance and delay.

Xiliang Zhong, Cheng-Zhong Xu [7] proposed a energy efficient scheduling policy in which independent process is only a special case. The objective is minimizing the average transmission energy expenditure under individual packet delay constraints.

Alvin Fu, Eytan Modiano, and John N. Tsitsiklis [8] proposed a dynamic algorithm used to generate optimal solutions to the dual problems of maximizing expected throughput given limited energy, and of minimizing expected energy given minimum throughput constraints.

3. Proposed Design

This section provides the joint optimization of control and communication system with the aim of minimizing the energy consumption data transmission for wireless networked control system. While designing the joint optimization of control and communication system consider the constraint for guarantying stability of the control systems and maximum transmit power and schedulability constraints of the wireless communication system. The main objective in formulating is the switch-off between the control performance and the power consumption of the wireless communication network.

Fig. 1 shows the system architecture of WNCS where multiple plant devices are controlled over wireless network. As shown in figure, we assume that sensor nodes are attached to the each plant devices. Sensors collect the output of plant devices at every periodic interval which is

sampled periodically and then this sampled output is forwarded to the controller over wireless device. This information introduced delay and packet losses due to the time varying channel, interference and limited spectrum which affect the performance if the control system. As the controller receives the newest data from the plants they computed the control command.

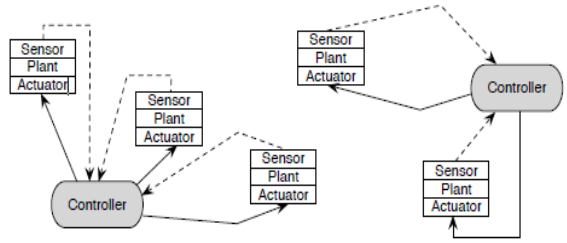

Fig. 1. Overview of the WNCS setup.

After that, the control command is forwarded to the corresponding actuator attached to the plant. Plants will not update their status until they receive the newest command from controller.

For solving the optimization problem proposes efficient solution methods for the network containing one sensor node and multiple sensor node respectively.

3.1 One Sensor Case

The joint optimization of control and communication system for the wireless network containing one sensor node formulated as that include the power consumption. By formulation the sufficient schedulability obtained in wireless communication. But the resulting optimization problem is again a non-convex Mixed- Integer Programming problem thus difficult to solve for the global optimum. However by analyzing the optimality conditions on the variables of the problem allows us to reduce it to an Integer Programming problem

3.2 Multiple Sensor Case

The joint optimizations of control and communication system for the wireless network containing multiple sensor nodes only produce some additional schedulability constraint. These constraints only necessitate a join design for multiple sensor nodes. This is again a optimization problem like one sensor node that is solved by heuristic algorithm [4]. Which the essential constraint on the constellation sizes is removed is again a convex optimization problem. The resulting optimal values of the constellation sizes are possibly non integer therefore ceiled to obtain an integral solution while avoiding the violation of the schedulability constraint.

The overall procedure uses the energy minimizing schedule generation algorithm for providing schedulability. This will provide stability to the wireless network. In the each iteration of the algorithm the optimization problem is solved which will help in determining the optimal delay. Then, construct a viable schedule with optimal delay and period over one scheduling frame.

Table 1.Comparsion of Algorithm

Parameters	**Algorithms**	
	Uniform energy algorithm[1]	**Heuristic algorithms [4]**
Network Overhead	Less	Less
Throughput	More	More
Packet loss	Less	Less
Success Rate	More	More

4. Conclusion

The paper proposed the joint optimization of control and communication system with the aim is to minimum energy consumption in data transmission for wireless networked control system. The proposed research its self with two tasks. One is to formulate the optimization problem as a Mixed-Integer Programming problem. Second task, by analyzing the relation of the optimal sampling period and packet error probability to the reduced it to the Integer programming problem for which we proposed an efficient solution method. Simulation results show that our algorithm obtains a 95% improvement as compared to the case of a stationary base station

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Acknowledgments

The work was carried out under the guidance of Ms. Ranjana Shende, Assistant Professor at G.H. Raisoni college of Engg and Tech. The author would like to thank respected teacher for his valuable comments and guidance.

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