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Le Contrôle de Congestion et la Fiabilitlé dans les Réseaux de Capteurs sans Fil

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Abstract

A wireless sensor network is a set of hundreds or thousands tiny nodes equipped with embedded computing devices, interfacing with sensors/actuators, and scattered in order to monitor a specific area and forward the happening events to a specific unit, named sink or base-station. The main advantage of using WSN, that becomes feasible with the micro circuitry evolution, is that each sensor is a low cost device with very limited capacities in terms of processing, memory storage, communication range and power supply, but which brings its strength from being used cooperatively with other ones through the construction of a large, self-organized, multi-hop network to sense accurately critical events happening. Numerous monitoring applications could be concretized using WSNs starting from civil ones (e.g: home automation and surveillance, fire detection, precision irrigation, healthcare application, industrial processing and control, urban traffic control, etc.) to military-based applications (e.g: battlefield monitoring, country borders surveillance, enemies tracking, etc.). Two types of flows characterize the WSN communications. Namely, the collected data from the events' sources towards the sink; and the dissemination of control commands, data queries and nodes' code reprogramming from the sink towards the entire or a part of the network. These two flows' types require a certain reliability level that differs according to the data packets' types and application criticality. Congestion occurs when the traffic load exceeds the available capacity on node level (buffer overflow) or link level (interference or contention). The delivery of traffic, even being well regulated, is hindered by the poor and time-varying channel quality, asymmetric communication channels, the need of multi-hop forwarding, and the hidden terminal problem, which make the congestion being severe. These circumstances lead that congestion causes the waste of the nodes' energy, but the most serious is that it degrades the event detection reliability. In traditional wired networks, reliability and congestion control solutions are guaranteed by transport protocols. But due to special features of WSNs, cross layer interaction solutions become necessary. Indeed, TCP (Transmission Control Protocol) and UDP (User Datagram protocol) show non capabilities to face WSN reliability and congestion problems. One of the major drawbacks of TCP is that it uses end-to-end retransmission-based recovery mechanism and interprets any loss as a congestion indication. In contrast, UDP is connectionless transport protocol and is not suitable due to lack of flow, congestion and reliability control mechanisms, which are critical in WSN applications. So, WSN based transport protocols should ensure diverse applications requirements like reliability, energy consumption and data timeliness.

During this thesis, we have treated the congestion and reliability topics. We have classified the state-of-the-art works concerning these two axes. A deep overview of used mechanisms was discussed and many shortcomings were highlighted. Depending on the control policy, congestion control protocols were divided into resource control vs. traffic control. Traffic control protocols were either reactive or preventive (avoiding). Reactive solutions were classified following the reaction scale, while preventive solutions were split up into buffer limitation vs. interference control. Resource control protocols were classified according to the type of resource to be tuned. For reliability part, the state-of-the art works were classified according to the required level of reliability, the manner to identify the reliability lack origins, and the control to recover this lack. The cross layer design between MAC, routing and transport layers presents a good concept to efficiently overcome the different reliability holes. In the third part of the thesis, we have treated the congestion detection phenomena. The motivation behind this part is

that event-based applications of Wireless Sensor Networks (WSNs) are prone to traffic congestion, where unpredicted event detection yields simultaneous generation of traffic at spatially co-related nodes, and its propagation towards the sink. This results in loss of information and waste energy. Early congestion detection is thus of high importance in such WSN applications to avoid the propagation of such a problem and to reduce its consequences. Different detection metrics are used in the congestion control literature. However, a comparative study that investigates the different metrics in real sensor motes environment is missing. In this part of the thesis, we have focused on this issue and compared some detection metrics in a testbed network with MICAz motes. Results show the effectiveness of each method in different scenarios and conclude that the combination of buffer length and channel load constitute the better candidate for early and fictive detection. In the fourth part of the thesis, we have dealt with congestion and interference control in wireless sensor networks (WSN), which is essential for improving the throughput and saving the scarce energy in networks where nodes have different capacities and traffic patterns. A scheme called IACC (Interference-Aware Congestion Control) was proposed. It allows maximizing link capacity utilization for each node by controlling congestion and interference. This is achieved through fair maximum rate control of interfering nodes in inter and intra paths of hot spots. The proposed protocol has been evaluated by simulation, where the results rival the effectiveness of our scheme in terms of energy saving and throughput. In particular, the results demonstrate the protocol scalability and considerable reduction of packet loss that allow to achieve as high packet delivery ratio as 80% for large networks. In the fifth part of the thesis, we have ameliorated the IACC scheme. In fact, the wireless shared medium leads to links interferences in addition to wireless losses due to the harsh environment. The effect of these two points translates on differences in links bandwidth capacities, lack of reliability and throughput degradation. In this part, we tackled the problem of throughput maximization and reliability insurance by proposing an efficient congestion control-based schedule algorithm, dubbed REFIACC (Reliable, Efficient, Fair and Interference-Aware Congestion Control) protocol. REFIACC prevents the interferences and ensures a high fairness of bandwidth utilization among sensor nodes by scheduling the communications. The congestion and the interference in inter and intra paths hot spots are mitigated through taking into account the dissimilarity between links' capacities at the scheduling process. Linear programming was used to reach optimum utilization efficiency of the maximum available bandwidth. REFIACC has been evaluated by simulation and compared with two pertinent works. The results show that the proposed solution outperforms the others in terms of throughput and reception ratio and can scale for large networks. In the sixth part of the thesis, we have proposed to apply our congestion control scheme for wearable health monitoring system. Indeed, the wearable sensors and their surrounding healthcare applications bring a lot of benefits to patients, elderly people and medical staff, so facilitating their daily life quality. But from a research point of view, there is still work to accomplish in order to overcome the gap between hardware and software parts. In this part, we have targeted the problem of congestion control when all these healthcare sensed data have to reach the destination in a reliable manner that avoids repetitive transmission which wastes precious energy or leads to loss of important information in emergency cases, too. We have proposed a congestion control scheme CCS_WHMS that ensures efficient and fair data delivery while used in the body wearable system part or in the multi-hop inter bodies wearable ones to get the destination.

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