UNIVERSITI PUTRA MALAYSIA

MULTI-CHANNEL SUPPORT FOR DATA-GATHERING TREES IN WIRELESS SENSOR NETWORKS

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BY

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MULTI-CHANNEL SUPPORT FOR DATA GAHTERING-TREES IN WIRELESS SENSOR NETWORKS

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September 2010

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In traditional applications of Wireless Sensor Networks (WSNs), energy efficiency may be considered to be the most important concern whereas utilizing the bandwidth and maximizing the throughput are of secondary importance. However, recent applications, such as structural health monitoring, require high amounts of data to be collected at a faster rate. Furthermore, it is possible to have multiple applications running on the same network, especially with some operating systems for WSNs. This certainly leads to larger amounts of data to be transmitted in the network and handling the traffic. In general, multi-channel scheme is widely used in wireless networks, to reduce the interference and to increase the throughput. Although that current radios support up to 16 channels, this is not enough to allow all of the nodes which are in the same interference range to transmit concurrently especially in dense networks. A new multi-channel duty cycle protocol, known as Adaptive Fast Convergecast MAC (AFC-MAC), is proposed especially for data gathering tree which combines the staggered wake up

schedule with the multi-channel approach to reduce the number of competing nodes in order to get a transmission. AFC-MAC composed of two phases, the channel assignment phase and the adaptive scheduling phase. The channels are assigned to the nodes in a way to allow the nodes to send the data packets with a minimum delay by eliminating the interference with the concurrent transmissions of the next nodes along the path, and at the same time the nodes consider the impact of the adjacent channels in the channel assignment decision. This interference elimination helps the nodes to schedule the next active time-slots time cycle with a minimum delay to adapt to the network's high traffic rate. The two-way data forwarding is supported by the adaptive schedule phase by adopting a special synchronization mechanism to avoid the contradiction with the sink's reports forwarding. One of the multi-channel duty cycle protocols, Path-Oriented Real Time MAC protocol (PR-MAC) is examined and simulated using the ns2 simulation environment. AFC-MAC is compared with PR-MAC in terms of Aggregate MAC throughput, delivery ratio, and energy efficiency. Since AFC-MAC assigns the channels to nodes rather than paths, the convergecast speed and the throughput has been enhanced. Specifically, the throughput is enhanced 4.784 times to the achieved throughput in PR-MAC, and the delivery ratio in AFC-MAC has been enhanced 2.242 times compared to PR-MAC.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia Sebagi memenuhi keperluan untuk ijazah Master Sains

SOKONGAN PELBAGAI SALURAN UNTUK PENGUMPULAN PEPOHON DATA DALAM RANGKAIAN PENDERIA TANPA WAYAR

Oleh

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Dalam applikasi tradisional Rangkaian Penderia Tanpa Wayar (WSN), kecekapan tenaga boleh dianggap sebagai ciri terpenting di mana kadar penggunaan jalur saluran dan pemaksimuman kadar pemprosesan diletakkan di takuk kedua. Walaubagaimanapun, dalam applikasi terkini, contohnya seperti pemantauan tunjang kesihatan, memerlukan pengumpulan amaun data yang banyak pada kadar yang lebih laju. Tambahan pula, adalah mungkin pelbagai applikasi berjalan serentak dalam rangkaian yang sama, terutamanya dengan beberapa sistem operasi tertentu untuk WSN. Ini sudah tentunya membawa kepada pemancaran amaun data yang lebih tinggi melalui rangkaian dan pengelolaan trafik. Secara umumnya, skim pelbagai saluran digunakan secara meluas dalam rangkaian penderia tanpa wayar, untuk mengurangkan interferens dan meningkatkan kadar pemprosesan. Walaupun radio masa kini mampu menyokong sehingga 16 saluran, namun ini masih tidak mencukupi untuk membenarkan semua nod yang berada dalam julat interferens memancar secara serentak terutamanya dalam rangkaian-

rangkaian yang padat. Satu protokol *duty cycle* pelbagai saluran yang bijak, *Adaptive Fast Convergecast MAC* (AFC-MAC), dicadangkan terutamanya untuk pengumpulan pepohon data yang menggabungkan jadual bangun berperingkat dengan menggunakan pendekatan pelbagai saluran untuk mengurangkan jumlah nod yang berlumba-lumba untuk mendapatkan transmisi. AFC-MAC terdiri daripada dua fasa, iaitu fasa peruntukan saluran dan fasa penyesuaian penjadualan. Saluran-saluran ini diperuntukkan kepada nod-nod dalam cara yang membenarkan nod-nod tersebut menghantar peket data dengan kadar pelambatan minimum dengan menghapuskan interferens melalui transmisi serentak nod-nod berikutnya sepanjang laluan itu, dan pada masa yang sama nod-nod tersebut mengambilkira impak terhadap saluran-saluran bersebelahan semasa keputusan peruntukan saluran dibuat. Penghapusan interferens ini menolong nod-nod tersebut untuk menjadualkan kitar masa slot-masa aktif yang berikutnya dengan kadar pelambatan minimum untuk menyesuaikan diri kepada kadar trafik rangkaian yang tinggi. Penyampaian data dua-hala disokong oleh fasa penyesuaian penjadualan dengan menggunakan mekanisma sinkronisasi khas untuk mengelakkan kontradiksi dengan laporan sinki penyampaian. Salah satu daripada protokol *duty cycle* pelbagai saluran, protokol *Path-Oriented Real Time MAC* (PR-MAC) dikaji dan disimulasi menggunakan persekitaran simulasi ns2. AFC-MAC dibandingkan dengan PR-MAC dari segi kadar pemprosesan Agregat MAC, nisbah penghantaran, dan kecekapan tenaga. Memandangkan AFC-MAC memperuntukkan saluran kepada nod dan bukannya laluan, kelajuan *convergecast* dan kadar pemprosesan telah berjaya dipertingkatkan. Secara terperinci, kadar pemprosesan dipertingkatkan 4.784 kali ganda berbanding dengan kadar

pemprosesan tercapai oleh PR-MAC, dan nisbah penghantaran dalam AFC-MAC telah berjaya dipertingkatkan 2.242 kali ganda berbanding dengan PR-MAC.

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I certify that a Thesis Examination Committee has met on (29/9/2010) to conduct the final examination of Wasan Ahmad Sulieman Alfraihat on his thesis entitled "**Multi-Channel Support For Data Gathering Trees in Wireless Sensor Networks**" in accordance with the Universities and University Colleges Act 1971 and the constitution of the University Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science in Wireless Communication Engineering.

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DECLARATION

I declare that this thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at University Putra Malaysia or at any other institution.

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Date: 29/9/2010

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