Faculty of Electronics and Computer Engineering

DESIGN AND MODELLING OF AN ENERGY AWARE DYNAMIC MANAGEMENT FOR WIRELESS SENSOR NODE WITH DUAL HARVESTERS

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DECLARATION

I declare that this thesis entitled "Design and Modelling of an Energy Aware Dynamic Management for Wireless Sensor Node with Dual Harvesters" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : Ali Mohammed Abdal-kadhim

Date : 1/7/2020

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature : .....

Supervisor Name : Associate Professor Dr. Kok Swee Leong

Date : 1 / 7 /2020

DEDICATION

For my family who helped me in all things great and small.

ABSTRACT

Wireless Sensor Network (WSN) consists of a large number of spatially distributed low-power autonomous nodes equipped with sensors to cooperatively monitor the environmental conditions. The limited battery lifespan that is being used by a sensor node is the major bottleneck that restricts the extension of WSN application for its scalability and sustainability. Thus, the energy consumption efficiency remains the most prominent design criterion that need to be addressed urgently. There are two main research concerns on the energy-harvesting powered WSN, firstly is to reduce the node power consumption and the, secondly is to increase the harvesters' power to meet the minimum requirement of the node power consumption. In another word, it is to reduce the mismatch of the supply and demand of the node electrical power. Thus, an energy aware dynamic management model for wireless sensor node powered by dual harvesters is presented to deal with the mismatch. The first step of the research is to investigate the node power consumption profile. This is followed by investigating the electrical power supplies which are based on thermoelectric and piezoelectric as Hybrid Energy Harvesting (HEH). The node is designed with a built-in main and backup energy storages to overcome the HEH energy gap issue. It features fast start up using a small capacitive energy storage as the main instantaneous power source. Whilst for wider energy gap coverage, a larger capacitance is used as the backup energy storage. To reduce the power consumption while not compromising the integrity of the signal transmission, the sensor node is improved with a novel energy-aware Event-Priority-Driven Dissemination (EPDD) algorithm. It is developed to make the sink station able to detect a missing node within the network. The function of the algorithm is to detect the energy sources availability and control the nodes' sleeping period accordingly. The empirical power profiling for each node and at system level were measured during active and sleep modes, which provides a useful data for designing low-power wireless sensor node. The node is designed and modelled using Matlab Simulink 2016 environment. The simulation results show an improvement in the node start-up time of less than 30s only with 48 hours of energy gap coverage, which is theoretically long enough to ensure that the node stayed active until the next phase of ambient energy to be available again. The experimental results are in good agreement with the simulation model. It is also found that the RF transceiver consumed the highest power of 24mW, followed by the microcontroller with 7.5mW and the sensor module with 0.16mW throughout the active period. During the sleep period, however, the microcontroller consumed a noticeable amount of power of 1.8mW compared to the other sensor node components. Moreover, it shows that energy at ideal cases where both energy harvesters, HEH are operating at the same time, a power in the range of around 90 mW is generated which is more than enough to achieve the minimum requirement to operate a sensor node.

ABSTRAK

Rangkaian Penderia Tanpa Wayar (WSN) terdiri daripada sejumlah besar nod autonomi berkuasa rendah yang bertaburan serta dilengkapi dengan penderia untuk memantau keadaan persekitaran. Nod penderia menggunakan bateri yang mempunyai jangka hayat terhad adalah penghalang utama bagi WSN dalam perkembangaan penggunaan lanjutan berskala besar dan kelestariannya. Oleh itu, kecekapan penggunaan tenaga adalah kriteria reka bentuk utama yang perlu ditangani segera. Penyelidikan ini terdiri daripada dua pertimbangan utama, yang pertamanya ialah mengurangkan penggunaan kuasa oleh nod dan keduanya ialah meningkatkan kuasa penuaian untuk memenuhi keperluan minima penggunaan kuasa pada nod. Dalam kata lain, ia adalah untuk mengurangkan ketidakpadanan pembekalan dan permintaan kuasa elektrik oleh nod. Dengan demikian, model pengurusan dinamik yang peka dengan penggunaan tenaga untuk nod penderia tanpa wayar yang dibekali kuasa oleh dua penuai dicadangkan untuk menangani ketidakpadanan tersebut. Langkah pertama penyelidikan ini ialah menyiasat profil penggunaan kuasa pada nod. Ia diikuti dengan menyiasat bekalan kuasa elektrik Penuaian Tenaga Hibrid (HEH) yang dijana berdasarkan termoelektrik dan piezoelektrik. Nod tersebut direka dengan simpanan tenaga utama dan sokongan tenaga terbina dalam untuk mengatasi isu jurang tenaga HEH. Ia memaparkan operasi permulaan yang cepat dengan menggunakan simpanan tenaga kapasitif yang kecil sebagai sumber kuasa utama seketika. Sementara itu, untuk liputan jurang tenaga yang lebih luas, kapasitan yang lebih besar digunakan sebagai simpanan tenaga sokongan. Bagi mengurangkan penggunaan kuasa sambil tidak menjejaskan integriti penghantaran isyarat, nod penderia tersebut ditambahbaik dengan algoritma "Event-Priority-Driven Dissemination" (EPDD). Ia dibina supaya stesen pangkalan dapat mengesan nod yang hilang dalam rangkaian tersebut. Fungsi algoritma tersebut ialah untuk mengesan ketersediaan sumber tenaga dan mengawal tempoh tidur nod mengikut kesesuaian. Profil kuasa empirikal untuk setiap nod dan sistem secara keseluruhan diukur semasa mod aktif dan tidur, yang menyediakan data yang penting untuk pertimbangan semasa merekabentuk sesuatu nod penderia tanpa wayar berkuasa rendah. Nod tersebut direkabentuk dan dimodelkan dengan menggunakan Matlab Simulink 2016. Hasil simulasi menunjukkan tambahbaik pada masa operasi permulaan nod kurang daripada 30 saat dengan liputan jurang tenaga selama 48 jam, yang secara teorinya cukup panjang untuk memastikan bahawa nod kekal aktif sehingga tenaga persekitaran kembali pada fasa seterusnya. Keputusan eksperimen didapati adalah sepadan dengan model simulasi. Ia juga didapati bahawa penghantar-terima RF telah menggunakan kuasa tertinggi iaitu sebanyak 24mW, diikuti oleh mikropengawal dengan 7.5mW dan modul penderia dengan 0.16mW sepanjang tempoh aktif. Walau bagaimanapun, semasa tempoh tidur, mikropengawal menggunakan sejumlah kuasa yang ketara iaitu 1.8mW, berbanding dengan komponen lain dalam nod penderia tersebut. Selain itu, ia menunjukkan bahawa pada kes yang ideal, di mana kedua-dua penuai tenaga beroperasi serentak, ianya dapat menghasilkan kuasa sebanyak 90 mW, yang memadai untuk mengatasi keperluan minima operasi sesuatu nod penderia.

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