UNIVERSITI PUTRA MALAYSIA

DYNAMIC AREA COVERAGE ALGORITHMS FOR STATIC AND MOBILE WIRELESS SENSOR NETWORK ENVIRONMENTS USING VORONOI TECHNIQUES

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By

OMAR M. CEESAY

Thesis Submitted to the School of Graduate Studies, University Putra Malaysia, in Fulfillment of the Requirement for the Degree of Master of Science

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This thesis is specially dedicated to my dear family and longtime friends: first and foremost, to mum and dad Betty Kebbeh and Manlafy Ceesay who have been very instrumental in my religious, social and academic upbringing;

My brothers: Lamin, Pha Kebbeh, Buba, Musa, Ebrima, Sheriffo and Baba;

my sisters Isatou, Arokey, Nyima (Njonji), Aja, Nabintou, Fatoumatta, Maa, Mariama, Kaddy and Kumba;

My friends: Mass, Madi, Edrissa, Sainey, Fa Sillah, Jerreh, Alieu, Yorro, Kebba and Saikouba.

Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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Chairman: Mohd. Fadlee A. Rasid, PhD

Faculty: Engineering

In recent years, Wireless Sensor Networks (WSNs) have gained significant research attention due to their prospects in various applications. In most application scenarios, good network coverage of the phenomenon of interest has to be maintained in order to transmit the required data to the sink node. In large and hostile environments where random deployment is usually the most feasible option, large regions may be left without coverage because some of the nodes missed their target locations. Even where an initial full coverage is ensured, energy depletion and abrupt malfunctioning eventually leave large areas in the network without coverage.

This thesis focuses on developing Voronoi Tessellation-based Coverage Optimization Algorithms for Static and Mobile Wireless Sensor Networks, where a large number of static nodes are supported by few mobile nodes in carrying out the sensing task.

Voronoi tessellation consists of a set of sites in a plane partitioned in such a way that the entire region within any one of the partitions is closest to only one site than to any other site in the plane. The sites are the static sensor nodes and the partitions, the voronoi polygons. Each voronoi polygon is bounded by edges and vertices. A voronoi edge is the line equidistant to two adjacent voronoi sites (static nodes). A voronoi vertex on the other hand is formed by the intersection of three or more voronoi edges.

After deployment, static nodes communicate among themselves to form their Voronoi polygons, such that each polygon consists of only one static node. Since voronoi tessellation alone can only generate voronoi vertices inside the network, static nodes along the network boundaries discover their vertices along the boundary by using a Boundary Vertex Discovery Model, which is proposed in this thesis. Each static node then checks whether there exist a region in its polygon without coverage. If a coverage-hole is found, static nodes compute the size of the hole and request mobile nodes to target locations for optimal coverage. In order to ensure the shortest path movement of mobile nodes to target locations, a Matrix Row/Column Elimination model is proposed.

The proposed Voronoi Tessellation-based Coverage Optimization Algorithms for Static and Mobile Wireless Sensor Networks provides up to 99% coverage at various number of mobile-static sensor node combination and up to 12% reduction in average moving distance. Moreover, energy consumption as well as the number of deployed nodes is

minimized, while maintaining the same level of coverage compared to existing coverage models.

Abstrak tesis ini dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master of Science

ALGORITMA LIPUTAN KAWASAN DINAMIK UNTUK PERSEKITARAN RANGKAIAN PENDERIA TANPA WAYAR STATIK DAN BERGERAK MENGGUNAKAN VORONOI TEKNIK

Oleh

Omar M. Ceesay

June 2011

Pengerusi: Mohd. Fadlee A. Rasid, PhD

Fakulti: Kerujuteraan

Pada masa ini, Rangkaian Penderia Tanpa Wayar (WSN) telah mendapat tumpuan yang meluas dalam bidang penyelidikan berdasarkan prospeknya dalam pelbagai aplikasi. Di dalam kebanyakan senario aplikasi, liputan rangkaian yang baik terhadap fenomena yang dikehendakki mestilah berterusan untuk memastikan data dapat dihantar ke nod sink. Di dalam persekitaran yang luas dan terpencil dimana pengaturan kedudukan hanya boleh dilakukan secara rawak, berkemungkinan terdapat kawasan yang tidak mendapat liputan kerana beberapa nod mungkin terlepas lokasi sasarannya. Walaupun pada awalnya liputan penuh telah dipastikan, penyusutan tenaga dan kepincangan tugas yang mendadak, sedikit demi sedikit akan menyebabkan kawasan yang luas terbiar tanpa liputan. Objektif tesis ini adalah untuk membangunkan Algoritma Pengoptimuman Liputan berasaskan Teselasi Voronoi untuk WSN Statik dan Bergerak, dimana sejumlah besar nod statik disokong oleh beberapa nod bergerak dalam menjalankan tugas penderiaan.

Voronoi teselasi terdiri daripada satu set tapak-tapak pada satah yang disekat agar keseluruhan kawasan di dalam mana-mana sekatan adalah terdekat kepada hanya satu tapak daripada lain-lain tapak di dalam satah. Tapak-tapak ini adalah nod-nod pengesan statik manakala sekatan-sekatannya adalah poligon voronoi. Setiap poligon voronoi dibatasi oleh tepian-tepian dan bucu-bucu. Tepian voronoi adalah garisan samajarak daripada dua tapak voronoi bersebelahan (nod-nod statik). Manakala bucu voronoi pula dibentuk dengan menyilangkan tiga atau lebih tepian-tepianvoronoi.

Selepas pengaturan kedudukan, nod-nod statik akan berkomunikasi sesama sendiri untuk membentuk poligon-poligon Voronoi, dimana setiap poligon mengandungi hanya satu nod statik. Oleh kerana teselasi Voronoi hanya mampu menjana bucu-bucu Voronoi di dalam rangkaian, nod-nod statik di sepanjang sempadan rangkaian menemukan bucu-bucunya di sepanjang sempadan dengan menggunakan Model Pencarian Bucu Sempadan, yang dicadangkan di dalam tesis ini. Setiap nod statik kemudiannya memeriksa samada terdapat kawasan tanpa liputan di dalam poligonnya. Sekiranya lubang liputan dijumpai, nod statik akan mengira saiz lubang tersebut dan meminta nod-nod bergerak ke lokasi sasaran untuk mengoptimumkan liputan. Untuk memastikan laluan terpendek bagi pergerakan nod bergerak ke lokasi sasaran, model Penyingkiran Baris/Lajur Matriks dicadangkan.

Algoritma Pengoptimuman Liputan berasaskan Teselasi Voronoi untuk WSN Statik dan Bergerak menghasilkan sehingga 99% liputan pada pelbagai kombinasi nod bergerak-statik dan sehingga 12% pengurangan jarak pergerakan purata. Malahan, penggunaan

tenaga dan bilangan nod yang perlu diletakkan juga diminimumkan, di samping mengekalkan paras liputan yang sama dengan model liputan sedia ada.

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I certify that a Thesis Examination Committee has met on 30 June 2011 to conduct the final examination of Omar M. Ceesay on his thesis entitled "Dynamic Area Coverage Algorithms for Static and Mobile Wireless Sensor Network Environments Using Voronoi Techniques" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the 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 Universiti Putra Malaysia or at any other institutions.

OMAR M. CEESAY

Date: 30 June 2011

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