行政院國家科學委員會專題研究計畫　期中進度報告

子計畫二：感測網路於居家照護之應用(1/3)

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執行單位：國立臺灣大學電機工程學系暨研究所

計畫主持人：黃寶儀

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行政院國家科學委員會專題研究計畫 期中進度報告

感測網路於居家照護之應用 (1/3)

Sensor Network for Home Care (1/3)

計畫編號：NSC 93-2218-E-002-147
執行期間：93 年 10 月 1 日 至 92 年 9 月 31 日 (第一年)

執行單位：國立台灣大學電機工程學系暨研究所
計畫主持人：黃寶儀
計畫參與人：劉承榮、張庭豪、黃信榮

一、中英文摘要

感測器(sensor)與無線感測網路(sensor network) 的研究及技術逐漸成熟，使其在智慧型系統的應用上受到廣泛的注目。智慧型系統可以利用感測網路收集到的環境參數，達成使用者與系統間輕鬆且聰明的互動。未來幾年，無線感測網路的發展將大幅推進至諸如軍事、工業、生態環境研究等方面的應用。因應現今社會人口老化，慢性疾病人口增加的趨勢，本計畫特別著眼於無線感測網路在智慧型居家照護(intelligent home care) 上的應用。在這個應用領域，無線感測網路扮演了收集老人居家生活情形中各種參數的重要角色。

有別於目前的技術，無線感測網路用於居家照護的設計上有三個特點：固定與行動節點並存、資料種類的多樣、及感測資料傳達的即時性。在設計創新及技術轉移可行性並重的前提下，我們提出了（一）adaptive diffusion 、（二）fast content-based forwarding 、及（三）two-class service differentiation 來因應前列三項特性的需要。Adaptive diffusion 是一個以資料為中心的調整型路由機制。Fast content-based forwarding 可望解決比對資料內容的速度問題。Service differentiation 則增加即時資料取得的可靠與容錯性。我們的目標是在三年內進行整體計劃的評估、實作、與整合，並期領先全球完成無線感測網路於智慧型居家照護的應用及實作。研究成果將奠定台灣在無線感測網路於一般消費市場研究與應用的全球策略性地位，並開創System on Chip (SOC) 在，以感測器與感測網路為基礎的智慧型應用上，一個全新的發展空間。

Recent technology and research advances have helped paving the way to the pervasive deployment of sensors and sensor networks everywhere. These give rise to a new generation of intelligent applications. Sensor data about the target of observation or the environment are essentially the insights to enable effortless interactions between the users and applications. The emergence of sensor network technology would impact a broad variety of applications from national security to infrastructure monitoring. In this project, we seek the applications of sensor networks in the domain of consumer electronics, and in particular intelligent home care. In that, the sensor networks play the critical role of collecting sensor data that indicate the well being of the elders living in place.

The design of sensor network for home care is unique in three aspects – co-existence of static and mobile sensors, variety of data types, and mission-criticalness of data for elder care. Emphasizing both the engineering innovation and practical business solution, we propose 1) adaptive diffusion, 2) fast content-based forwarding, and 3) two-class service differentiation that address the above three challenges. The adaptive

diffusion is a data-centric path finding (routing) mechanism, which prefers the selection of stable and energy-abundant routes. The fast forwarding algorithm handles, in low space and time complexity, the content-based table lookup problem. The service differentiation enables mission-critical data to be sent in high priority and redundancy. Our objectives in this project are to systematically evaluate, validate, implement, and integrate the sensor network to the overall home care system – iCare.

We expect, as a result, to lead the world in the research and development of sensor network based intelligent home care system. The expertise built up by the project will put Taiwan at a vintage point in the R&D of sensor networks in consumer electronics. This will also pave a brand new avenue for System on Chip (SOC) design and inspire a new generation of consumer demands for ubiquitous intelligent applications.

二、計畫目標與規劃

Our goal in this sub-project is to build a sensor network framework that meets the above challenges. That is to say the communication protocol should be:

1 configuration free
2 discriminative of urgent and non-urgent data
3 adaptive to the system residual energy on the mobile wireless nodes
4 fast in heterogeneous sensor data forwarding
5 efficient in computation, memory, and bandwidth use.

The communication system architecture is depicted in Figure 1. It contains a data-centric core and an extendible and composable application-dependent service level. With the building blocks supplied by the core and service level composability, we achieve in discriminating data by providing different services for application needs.

The **data-centric core** is responsible for the fundamental tasks of routing and forwarding. The routing component provides a broadcast service and a many-many routing service that is adaptive to the residual system power level of mobile wireless sensor nodes. The forwarding component provides a 2-level priority forwarding service.

The **application-dependent service level** could contain services composed by the primitives provided by the communication core. In the context of home care, the two data dissemination services defined are 1) broadcast and priority forwarding for the urgent data and 2) adaptive many-cast and regular forwarding for the non-urgent data. The urgent data in the home care system are disseminated aggressively --broadcast in high priority. This would avoid congestion, reduce delay, and prevent from data loss to the best quality the network can sustain.

The adaptive data-centric routing and fast data forwarding are the **key research components**. The adaptive data-centric routing protocol promises to avoid transiting data through more energy limited mobile wireless nodes and therefore prevent from the inconvenience caused by the repeated changes of batteries of the sensor nodes. The fast data forwarding mechanism is essentially a string matching problem. The efficiency will impact greatly the delay and loss rate the sensor network will experience. Our premise is to adopt a fast string matching algorithm for sensor data forwarding to ensure the quality of the data dissemination.

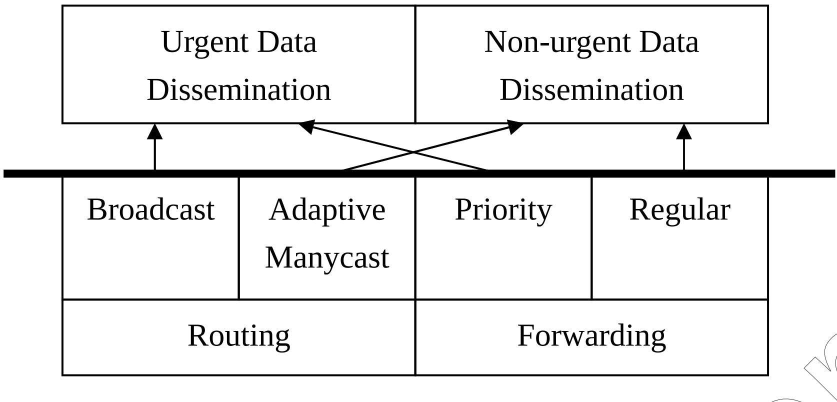

Figure 1. The communication system architecture for home care sensor networks.
Application-dependent services: urgent and non-urgent Data Dissemination
Data-centric core: broadcast/adaptive manycast; regular and priority forwarding

The task breakdown and project timeline is illustrated in Table 1. What highlighted are **tasks completed so far**. We have completed what have been planned for the first year. In particular, for the adaptive diffusion and fast forwarding parts, we are ahead of the schedule.

Timeline	Tasks Work Flow	Adaptive Diffusion	Fast Forwarding	Service Differentiation
1st Year	Lit. Review	Data-centric delivery	String search algorithm	Sensor network QoS
	Design	Bandwidth usage and delay analysis Protocol Specification	Complexity analysis Pseudo code	Data prioritization for desired QoS Mechanism
2nd Year	Evaluation	ns-2-based simulation	Implementation on Linux-based embedded systems	ns-2-based simulation
	Validation	Implementation and APIs on sensor notes	Implementation and APIs on sensor nodes	Implementation and APIs on networked embedded Linux devices
3rd Year	Deployment	Integration and porting of the adaptive diffusion, fast forwarding, and service differentiation mechanisms to the actual devices		

Table 1. Task Breakdown

三、分析與討論

Data-centric routing: Magnetic Diffusion

Magnetic diffusion (MD) is a simple data dissemination mechanism that promises all the above properties. The inspiration comes from the magnetic interactions in the nature. Consider the data sink as a magnet and the data as nails. The data will be attracted towards the sink according to the magnetic field just as the metallic nails being attracted towards the magnet. The magnetic field is established by setting up the proper magnetic charges on the sensor nodes within the range of data sink. The strength of the charge is determined by the hop distance to the sink and the level of resource available at the sink. The data will be propagated based on the magnetic field from low to high magnetically charged nodes. This way of disseminating data results in optimal delay multi-path forwarding.

In [2][3], we are able to demonstrate through the simulation results that MD does 1) perform the best in timely delivery of data, 2) achieve high data reliability in the presence of network dynamics, and yet 3) work as energy efficiently as the state of the art mechanisms. We thus conclude that MD is a promising data dissemination solution to the mission-critical applications.

Fast Forwarding: Suffix Tree

Suffix tree (Abbreviate as ST) is a well-known data structure which is extensively used in bio-informatics. The first paper mentioned about fast construction is presented in [5]. The fast construction algorithm allows us to build a suffix tree in linear time. ST is also an efficient search utility when dealing with long strings such as genetic sequence. ST can complete an single attribute-value matching, a search or an insertion in O(| P|) time where |P| represents the length of input sting. For super string search. ST can accomplish a single task in O(|S|) steps if the relation of substring between training strings are figured out during the insertion time. We would like to apply ST on the attribute and predicate matching part of sensor network forwarding systems.

The state of the art is ternary search tree (We will use the abbreviation "TST" in the rest of the paper). It is an old but efficient data structure for string matching. In each TST, every node has three children, namely, left-child, middle-child and right-child. For any arbitrary node N, there's a character c which represents a tag for string matching. The left-child contains all substrings that are alphabetically smaller than c, middle-child denotes substrings that start with a character c, and right-child includes all substrings that begin with a character greater than c. TST is an efficient algorithm, it can complete an exact string search in O(log(n) + |S|) steps where n is the total number of strings in TST and S denote the length of the input string. In the super string search cases. TST can finish the search in O(|S|log(n) + |S|2) steps.

Aside from the above two complex data structures, we also adapt string hash table with a rotation-based hash function as one of our candidate solutions. In the hash table implementation, every input string has a hash value, which indicates the position in the string table. The performance of hash table really depends on the design and adjustment of the hash function. It is generally fast and low memory consumption but still has some weak points. For example, it is hard to implement a substring or super string matching by using merely a hash table while there are already efficient ways for such requirements. The time complexity of a hash table based attribute-value matching with rotation algorithm is O(|S|) steps for hash value calculation and O(1) string comparisons. In the real implementation, we use a simple linked list structure to handle collisions.

We show in [3] the results of comparing the space and time complexity of the three algorithms implemented on embedded Linux-based devices. The results suggest that ST is computationally very efficient and the memory requirement is reasonable for most sensor network applications where the number of data types is in the scale of 100s.

四、成果自評

On results of magnetic diffusion for data-centric routing is to be published in a selective international conference, **the 8th ACM/IEEE International Symposium on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWiM 2005)**, Montreal, Qc. Canada, October 10-13, 2005. The acceptance rate is 21.8% this year. Subsequently, we submit the enhanced version with more detailed results to Computer Communication (SCI) and is expected to be published in the 2nd quarter 2006. In addition, the fast forwarding algorithm comparison is under preparation and now in the 2nd draft editing. The work will be submitted to a relevant conference in the near future.

五、參考文獻

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