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**Poster Presentation Abstracts
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1. Implementation of Ant Routing in SNET with Structure Attributes

Collections of ants form decentralized and autonomous swarms. As individuals, they behave with simple local rules while as a collection they collaborate to achieve global goals. The goal of identifying optimal shortest weight routing in a wireless sensor network can be achieved by emulating the forage model of ant colonies. In this project we demonstrate how the use of attributed data can be used to enable ant-based-routing schemes.

The project focuses on realizing ant routing in SNET within our proposed attribute-based routing framework. It builds a virtual SNET environment and simulates multiple nodes that perform multiple independent tasks. The ant routing is implemented using the Java language with the intent of supporting mobile code.

Each node maintains an ant table and probability table to decide which neighbor be the next hop. The simulation shows that ants usually find an optimal route, however the best route is not guaranteed every time. The reliability of finding a best route depends on the total number of ants running in the network and transmission delay of each node.

Results indicate that more ants sent initially can result in higher probability of finding the best route. It is also shown that overload of the path degrades the quality of the route and suffers the best route chosen while transmission delay mainly affects the performance of the ant routing. The independence of the task and node is also implemented which implies that the mobile code transmission is feasible for our framework.

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2. Rule-Based Decision-Making Framework for Sensor Networks

Sensor networks are emerging as popular means for real-time information gathering and processing in diverse contexts – e.g., patient data monitoring in acute, chronic care and battlefield settings, environmental data from inhabitable terrains, surveillance data from video cameras in a high-security building or border patrol, etc.

We believe that for sensor networks to succeed in the envisioned heterogeneous environment, the processes used to program and/or retarget them must be seamless. Towards that goal, we propose a general rule-based system that allows for unified sensory information processing and retrieval through the SNBench framework.

The SNBench framework allows us to easily recast our rule-based system to other application domains -- including the use of completely different sensor modalities or communication and networking infrastructures. In our system, an application is a set of event-driven tasks where events are triggered by sensors and carry some form of sensory data. Data is delivered to the SNBench where further processing and/or information dissemination to relevant actuator application takes place.

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3. Localization in Sensor Networks

This poster presents a robust location detection system using wireless sensor network. The location detection problem is posed as a composite hypothesis testing problem for improving system robustness instead of hypothesis testing problem. The generalized likelihood ratio test (GLRT) gives out asymptotically optimal result under some specific condition. We present the advantage of composite hypothesis testing to trade off the system performance with system training work. Furthermore, we compare the communication and local processing cost between centralized and decentralized models for our location detection problem. We also compare the performance of the location detection system under a sensor mesh network with multi-frequencies and multi-power levers and one frequency and one power levers by GLRT in the sense of probability error and error distance.

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4. Online Dynamic Voltage Scaling in Energy-Limited Non-Preemptive Systems with Real-Time Constraints

Dynamic voltage scaling is used in energy-limited systems as a means of conserving energy and prolonging their life. We consider a setting in which the tasks performed by such a system are non-preemptive and aperiodic. Our objective is to control the processing rate over different tasks so as to minimize energy subject to hard real-time processing constraints. We prove that the optimal solution to the on-line version of the problem can be efficiently obtained by exploiting the structure of optimal sample paths, leading to a new dynamic voltage scaling algorithm termed "Critical Task Decomposition Algorithm" (CTDA).

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5. Self-Repairing Spanning Tree in Changing Topology

We propose a communication protocol among a population of mobile autonomous agents that maintains a spanning tree interaction architecture although the underlying communication topology changes. We use a discrete wave equation on the topology and Courant's nodal domain theory. This protocol may help wireless/leaderless/mobile communications.

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6. A Control and Optimization Science Base for Sensor Networks in Adverse and Stochastic Environments

The poster presents a control and optimization science base for sensor networks in adverse and stochastic environments. The main research results include statistical location detection, efficient and fair transmission policies and quality of service routing to trade off energy consumption and latency.

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7. Constructing a Multi-Modal Wireless Network Security Service on snBench

The snBench (Sensor Network workBench) provides an extensible framework for quickly developing and deploying sensor network applications on a shared sensing infrastructure. The snBench's extensible architectural allows an engineer to quickly interface new modalities and sensing capabilities into the framework that may in turn be leveraged by novice SN programmers. This presentation illustrates our most recent work, extension of the snBench to integrate 802.11b/g wireless traffic monitors and a Pan-Tilt-Zoom camera network to develop a multi-modal network security monitoring service.

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8. A Joint Optimal Routing and Clustering Problem in Wireless Sensor Networks

An optimal control approach is used to solve the design problem in sensor networks where the goal is to maximize the lifetime of such network. Size of cluster and routing schemes are closely related and determine network lifetime jointly. We first show that shortest path routing scheme is no longer the optimal policy to prolong the network lifetime in such setting and uniform clustering policy ignores the structure properties and is far from optimality. We propose solving the non-linear programming problem using decomposition techniques and policies can significantly improve the overall objective.

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9. Efficient Reprogramming Framework for Wireless Sensor Networks

We propose a framework for the efficient reprogramming of subsets of a wireless sensor network. Our scheme relies on predicates guiding the distribution of tasks wherein tasks serve as the logical programming units mapped to nodes in the network. This approach is expected to achieve significant gains over whole application reprogramming found in over-the-air reprogramming models.

By studying the application function of the motes, we create independent tasks corresponding to different missions to be programmed onto the SNET. Each of these tasks is then dynamically installed based on distribution predicates. We also assign every message a task signature and map them to a particular task module in the task set. Thus far, the mote's behavior appears as a simple message forwarder directing incoming data messages to matching task components.

We have achieved a network prototype running this framework under a wired IP test bed using the mobile code transmission capability provided by the Java 2 Platform. Our prototype can dynamically install task module on the appointed computer and thus is successful in the incremental updating for the wireless sensor network application.

We believe our scheme results in the following benefits: First, the decomposition process makes the onerous work of network updating to be an easier job of updating individual task module on each mote. Second, we have achieved runtime application updating. Each installation of task module has no direct impact with the running application. Moreover, the behavior of the network is not be interrupted which is always a pain for the traditional over the air programming. Third, we simplify network reprogramming. The reprogramming of wireless sensor network is converted to the work of finding the mapping rule between the message set and task set. This new primitive is more flexible and suitable for general purpose wireless sensor network applications.

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10. Real-Time Spatio-Temporal Query Processing in Mobile Ad-Hoc Sensor Networks Project

Personal communication devices are increasingly equipped with sensors that are able to collect and locally store information from their environs. The mobility of users carrying such devices, and hence the mobility of sensor readings in space and time, opens new horizons for interesting applications. In particular, we envision a system in which the collective sensing, storage and communication resources, and mobility of these devices could be leveraged to query the state of (possibly remote) neighborhoods. Such queries would have spatio-temporal constraints which must be met for the query answers to be useful. Using a simplified mobility model, we analytically quantify the benefits from cooperation (in terms of the system's ability to satisfy spatio-temporal constraints), which we show to go beyond simple space-time tradeoffs. In managing the limited storage resources of such cooperative systems, the goal should be to minimize the number of unsatisfiable spatio-temporal constraints. We show that Data Centric Storage (DCS), or "directed placement", is a viable approach for achieving this goal, but only when the underlying network is well connected. Alternatively, we propose, "amorphous placement", in which sensory samples are cached locally, and shuffling of cached samples is used to diffuse the sensory data throughout the whole network. We evaluate conditions under which directed versus amorphous placement strategies would be more efficient. These results lead us to propose a hybrid placement strategy, in which the spatio-temporal constraints associated with a sensory data type determine the most appropriate placement strategy for that data type. We perform an extensive simulation study to evaluate the performance of directed, amorphous, and hybrid placement protocols when applied to queries that are subject to timing constraints. Our results show that, directed placement is better for queries with moderately tight deadlines, whereas amorphous placement is better for queries with looser deadlines, and that under most operational conditions, the hybrid technique gives the best compromise.

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11. Optimal Transmission Policies (Conflict-Free) for Large-Scale Wireless Sensor Networks

We consider wireless sensor networks with multiple gateways and multiple classes of traffic carrying data generated by different sensory inputs. The objective is to devise joint routing, power control and transmission scheduling policies in order to gather data in the most efficient manner while respecting the needs of different sensing tasks (fairness). We formulate the problem as maximizing the utility of transmissions subject to explicit fairness constraints. We propose an efficient decomposition algorithm drawing upon large-scale decomposition ideas in mathematical programming. We show that our algorithm terminates in a finite number of iterations and produces a policy that is optimal. We also demonstrate how to adapt our algorithm to accommodate energy constraints and node failures. The approach we introduce can efficiently determine optimal transmission policies for dramatically larger problem instances than an alternative enumeration approach. Furthermore, we develop an approach for obtaining optimal transmission policies for large-scale sensor networks where any simultaneous transmissions heard by a receiver cause a collision. The work has applications in a plethora of domains including process control, industrial automation, condition monitoring in manufacturing systems, indoor location detection, environmental monitoring, military, and homeland defense.

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12. Investigation of Current Technologies for Video Sensor Networks

Wireless sensor networks (SNETs) have established their viability in many application domains that exhibit low-data-rate and low energy consumption behaviors by virtue of their sensing properties. For example, wireless thermostats are only required to monitor and communicate a few bits of information at a period of order minutes. When one considers the possibility of incorporating the video modality, it appears that the volume and streaming nature of video data would overwhelm current sensor network platforms and system designs.

We seek opportunities to adapt event-driven in-network distributed processing to achieve a reduction in the aggregate video streaming data volume to enable video as a modality in future SNETs. In this poster we investigate and describe the state-of-the-art in video sensor networks (VSN) which can be largely categorized as (a) hardware platforms, (b) image processing, and (c) network communications.

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13. Robust Over-the-Air Programming Services for Wireless Sensor Networks

Current over-the-air programming (OAP) protocols operate on a single channel, determined at compilation time. Their performance degrades significantly as network density increases, due to increasing traffic contention. Furthermore, the use of a single channel makes OAP protocols particularly vulnerable to jamming and sniffing by malicious parties.

We propose a new method that harnesses the multi-channel transceiving capability of motes to speed-up over-the-air programming as well as enhance its security. We describe a preliminary implementation of this method on top of Deluge (the de-facto OAP standard), called Multi-Channel Deluge. Through experiments on a real testbed, we show that Multi-Channel Deluge can reduce the programming time of a sensor network by as much as 60% compared to the original version of Deluge.

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14. Optimal Cluster-Head Deployment with Redundant Link Requirement

We consider a two-level hierarchical wireless sensor network in which sensors are endpoints reporting to local cluster-head nodes, where data is processed and routed to the base station. As reliability is the paramount issue in industrial deployment, we enforce the requirement that each endpoint connects to multiple cluster-heads. The deployment of cluster-heads is formulated as a mixed integer, non-linear optimization problem aiming to reduce transmission power. We approach the difficult problem by exploiting structural properties and decomposing it into iterative convex programming problems which are easy to solve, and obtain sub-optimal solutions. An incremental deployment scheme is also proposed.

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