

## The summary of “ MODEL-DRIVEN DYNAMIC CONTROL OF ENBEDDED WIRELESS SENSOR NETWORKS”

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### SUMMARY:

This paper is describing a general framework for dynamic data-driven wireless network control along with the range of challenges that this control system and its designing will face and the solutions for the design of these dynamic sensor networks. The application that is being considering here *is the monitoring of physical environments and ecosystems, with the goal of predicting the biodiversity and carbon accumulation.*[1] We know that the rate at which the leaves gain the carbon and hence their growth depends upon many factors like moisture availability, change in temperature, and atmospheric CO<sub>2</sub> concentration. Different plants absorb carbon at different rates, so there is heterogeneous data. Also, given the physical reality of many applications like the expenses of physical transducers and the cost of deployment, focus is on the use of networks that are low in density and population with the sensors that are tightly coupled with the environment and both, networks and sensors, be smart enough to work adaptively with the changing sampling and communication needs in terms of evolving data acquisition and communication costs. So, the basic challenge is that the network should have adequate explanatory power under significant energy consumption constraint. So, these challenges along with the assimilation of heterogeneous data has shifted the focus on developing the statistically-aware, state-of-art dynamic models, which can assimilate heterogeneous data at different scales (the sampling interval may range from meters and seconds to landscapes and years), can evaluate the relative cost and value of this data collection and take the schedule actions accordingly.

The sensor networks perform two tasks - sensing and modeling. Sensing includes sampling (of the required data), communication (of the data with the network), estimation (of the value and cost of that data), and prediction (of the future activities). And later includes modeling of the sensor network and its embedding environment. There are both in-network and out-of-network components. In-network components are Network Inference and Prediction (NIP) for real-time assessment of the system, Dynamic In-Network Control (DINC) for real time adaptation, Dynamic Out-of-Network Control (DONC) for network analysis, adaptive deployment and trouble shooting, and Scalable Landscape Inference and Prediction (SLIP), for performing time-consuming, long-term, calculation intensive tasks like data assimilation from environment variables, tree growth and tree demography, and algorithm development to permit efficient computation for change over large landscape. *The in-network models will rely heavily on local, inexpensive information, informed by out-of-net models that fully exploit evolving global datasets. Because of computational and memory demands, SLIP will run on a server on cluster outside the wireless network itself. DINC responds to NIP predictions in real time, with updated scheduling based on optimization. NIP also passes information to DONC, which provides for more detailed assessment and control. Data ranges from long term (upto 15 yr) experiments involving manipulating canopy characteristic, CO<sub>2</sub>, herbivorous,*

*remote sensing, and wireless networks of environmental sensors. Models involve mass (water, CO<sub>2</sub>), and energy exchange, including basic tree physiology, and growth dynamics of trees.[1]*

Many complex models are made up of component models, which collaborate and compete with each other. Since communication is more expensive than computation so they compete more on communication costs. SLIP and NIP use Bayesian inference framework for estimation and prediction. The advantage of this framework is that the predictive intervals are directly anchored by the data. Hierarchical Bayes modeling can also be used which provides the basis for integrating the extensive data from a range of scales. Parametric modeling, is also used to provide the context, which may be spacial or temporal.

There is a prototype WiSARDNet (wireless sensing and relay device network) sensor network technology, that targets the applications in biological and ecological field research. It has two classes of nodes. Many nodes perform sensing and multihop networking and a few perform SLIP and DONC functions. Nodes have dual processor design. One is probe brain board that provides communication and networking services. Other is data acquisition board that perform sensing. On hardware level, there is three-board stack, where data probe is replaced by the gateways that provide communication interface and non-volatile memory. WiSARDNet's protocol stack design is driven by the sensing application and can be scheduled because of low temporal sampling, which improve the data quality by fixed average sampling. It is based on proactive coordination and scheduling. MAC algorithm is used that employ proactive coordination in slotted time frame ie node is awake only when communication is scheduled. This helps in energy saving and hence cost. Currently nodes with 8-bit processors are in use that have low power consumption but very limited computational capacity. But now next generation 16 and 32 bit processors are being introduced having more computational power than 8 bit processors and low power consumption than 32-bit architectures now used in rechargeable devices like PDA. Energy management in these devices is done by programmable system clock and low power instruction cache. Over-the-network dynamic reconfiguration is also needed that include loading new tasks and program and replacing the existing components. And it is done by module registration in SOS operating system. Module registration avoids calls to non-existing and outdated programs. All this is done at the hardware level. Sensor network operating system should include application level support of energy consumption management. The Energy Centric Operating System (ECOSystem) has demonstrated this.

Currently work is going on for building data service layer for WiSARDNet protocol. This is supposed to support high-level programming interface for specifying data acquisition tasks from both environment and system (battery life and storage capacity etc). This is jointly implemented by the central server and nodes. Central server performs optimization with previous assimilated data and produces a initial acquisition plan, which is divide into sub plans for nodes, that tell when and what to acquire. The fundamental building blocks of plans are *dynamic continuous queries* which are the streams of queries over the network where output of one query can be the input of other. *The data service component performs various functions: coordinates execution and adaptation of sub-plans and their interaction with WiSARDNet hardware probes and communication layer, tags data report with meta data about sampling and measurement condition, and provide*

*multi-resolution data storage within the network.*[1]

Environmental and system modeling offers many opportunities for optimization. SLIP can be used to quantify fidelity and utility of data in both accuracy and timeliness and use it to control sampling and reporting. Fidelity depends upon the usage and precision of the data required. Also DONC must consider requirements of multiple models. It can handle the fidelity requirements by using in-network NIP to achieve energy saving by not acquiring reading when utility is low, but only reporting the updates. There are the Reliability models which can provide reason for the error and failure.

In addition to getting the good computing power under energy constraints, there are some more algorithmic challenges that this system can face like defining the right utility and fidelity measures with as little resources as possible, providing algorithms for providing various trade-offs in dynamic sensor network. Some investigations have been done for analyzing trade offs between purely temporal model and spacio-temporal model. Other challenges are developing framework that can perform across multiple layers and across in and out network. Layers must coordinate. So should DINS and DONC.

#### **ANALYSIS:**

This project is showing very good implementation of DDDAS. It is data driven as it is assimilating the heterogeneous data and is using that data dynamically. To demonstrate the dynamic behavior it have incorporated many features. It can do task scheduling so that the network is active and data is transmitted only when it is required, and it only transmits the data that is different from the previous data and just updates the required parts instead of inserting whole information again or replacing the old content. Also, if assessment and prediction work can be done by in-network component, NIP, with required amount of accuracy and precision, then the interaction with out of network components and hence sensing operation can be avoided, that can save both cost and time. Other dynamic behavior it will show is that data can be sampled at required time and measurement scales which is the most important requirement in the type of application being considered here. Due to various issues and challenges addressed by this particular project, especially in context of the this application of analyzing the biodiversity and carbon accumulation, it can be applied to various other applications as well.

[1].Paul G. Flikkema<sup>1</sup>, Pankaj K. Agarwal, James S. Clark, Carla Ellis,Alan Gelfand<sup>2</sup>, Kamesh Munagala<sup>2</sup>,and Jun Yang, **Model-Driven Dynamic Control of Embedded Wireless Sensor Networks**, pg 409-416