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# Monitoring environmental factors in Mekong Delta of Vietnam using Wireless Sensor Network approach

Hoai Bao Lam, Hiep Xuan Huynh, Pierre Yves Lucas, Mahamadou Traore, Bernard Pottier

*Abstract* - **The paper is about monitoring the environment in the Mekong Delta of Vietnam. The delta is an important food supply area in Vietnam, with several environmental issues that may endanger the production. Among the issues are pest insects, saltwater intrusion, floods and water pollution. We are considering Wireless Sensor Networks (WSN) for understanding and controlling risks. A top down design method is investigated that allows geographic deployment, optimization of the layouts, and robust algorithms. This method is based on a simulation technique compatible with the synchronous behavior of the WSNs and future real time interactions.**

## I. Introduction

The Vietnam Mekong Delta is one of the great fertile plains in Southeast Asia and in the world. The natural area of the delta is 39.763 km$^2$ and the population in the end of 2010 was approximately 18 million [1]. The delta is a key food production area of Vietnam in which it is the largest food producers and has favorable conditions for the development of large-scale farming, especially raising coastal or fluvial aquaculture; for the high quality fruit-growing regions [1].

Rice is an important production of the Mekong Delta. Although the area of the Mekong Delta represents only 12.1% the area of Vietnam, half of the production and the majority of rice exports from the country is coming from this region. The average food per capita in the Delta is 2.3 times higher than the national Vietnam average[2].

The Mekong Delta also has a very strong aquaculture. Firstly, the delta is a key area for *brackish water shrimp* farming. In 2012, the shrimp farming area of the Mekong represented 90.6% of the total area in Vietnam, and reached 595.7 thousand hectares. In addition, production of shrimp harvested in the coastal provinces of the Mekong Delta contributed for 75.2% of whole Vietnam's production. Another fishery product of the delta is *shark catfish*. In fact, shark catfish (pangasius hypophthalmus) ranks in the 2nd position of seafood exports to foreign countries, shrimp holding the first rank [3]. Shark catfish lives mainly in the Mekong Delta and is raised in almost provinces in the delta, especially An Giang and Dong Thap. In 2012, the turnover of shark catfish export reached $1.74 billion, with a mass of about 1,255,500 tons [4].

However, The Vietnam Mekong Delta confronts with many environmental conditions that may endanger its food production. Although there exist practical solutions for these dangers, Information Technology tools are rarely used. This paper explains benefits coming from Wireless Sensor Network for remote data collection, understanding of biological processes, and eventual real time reaction to threats. The case used in this paper is the case of Brown Plant Hopper (BPH), a typical pest insect in Vietnam Mekong Delta, with the data collection in Dong Thap province, a typical rice province in Vietnam Mekong Delta.

This paper is organized as follows. Section 2 depicts some environmental factors that affect to Vietnam Mekong Delta and some current solutions for them in Vietnam. This is a followed by the explanation of WSN to monitor and control environment, in section 3. This section also mentions some tools to operate the simulation. Next section describes the design flow in NetGen [25] and some simulation results in light traps data in Dong Thap. In the last section we draw some conclusion regarding the presented work in particular, as well as possible future approaches in general.

The background of this paper is a work direction at Can Tho University, JEAI Dream group from the IRD, working in cooperation with the WSN group at University of Brest, Lab-STICC.

## II. Some environmental factors influence the Vietnam Mekong Delta

This section presents main characteristics of threats: pest insects, saltwater intrusion, floods, water pollution.

### A. Pest insects

The production of rice is the major target of several insects: *green leafhopper*, *zigzag leafhopper*, *white-backed plant-hopper*, *brown plant-hopper*, *rice whorl maggot*, *pink stem-borer*, and several unidentified species of leaf folders and stem borers [5].

The brown plant-hopper (BPH) is a major insect pest of rice in Mekong Delta, southern Vietnam. From 2005-2006, an outbreak of BPH occurred and two virus diseases were transmitted by BPH. Rice Ragged Stunt Virus disease (RRSV) and Rice Grassy Stunt Virus (RGSV) disease [6], spread over in the delta, resulting in big loss of rice production. Furthermore, in the same period, national rice production, and particularly the Mekong Delta production, suffered a major setback when outbreaks of BPH caused a loss of ~400,000 tons (1.1% of national production) [7].

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The outbreak of virus diseases transmitted by BPH has been the big challenge for the rice breeders, to find out the rice varieties with high yield and good grain quality, tolerant to BPH and virus diseases, suitable to different soil conditions. Some of the results were promising rice varieties tolerant to BPH, yellowing dwarf virus diseases, resistant to blast high and stable yield, tolerant to acid sulfate soils, suitable to alluvial soils and adapted to intensive cropping systems (MTL590, MTL603, MTL614, MTL631, MTL634, MTL637, MTL642, MTL645, MTL649, MTL653, MTL661, MTL662, MTL665, MTL706, MTL708 [13]).

Farmers may use pesticides to destroy BPH by direct spraying on young seedling of rice and seed treatment methods. By direct spraying, some pesticides are effective (such as Etofenprox, Fenobucarb, Carbosulfan, Thiamethoxam). By seed treatment methods, some insecticides are used: Thiamethoxam, Difenoconazole, Fludioxonil, Fipronil [8].

Besides this, insect light trap is one of the effective tools of insect pest management in organic agriculture. It mass-traps almost all of insect pests and also substantially reduces the carryover pest population. By monitoring the light traps, farmers will know better what types of insect are in their fields and if they are in a controllable level, or not [9].

To forecast the population of BPH, a sampling distribution with more than 340 light traps has been deployed in the Mekong Delta since 2005 [10].

A light trap uses light as an attraction source. Light traps depend on the positive phototactic response of the insects, as physiological as well as abiotic environmental factors can influence the insect behavior [11]. In the Mekong Delta, the light is usually turned on at 7:00pm everyday and the sample is collected and analyzed by farmers in the next morning [12].

Figure 1. A light trap beside a rice field. Top to bottom are a cover to protect from rain fall, a low energy bulb, glasses that are illuminated, a basin with water (sometimes insecticid) to kill insects. In this case, the power come from a farmer house close to the trap.


Figure 2. Layout of light traps (green spots) in Dong Thap district.

Figure 2 depicts light trap layout in Dong Thap province, a typical rice province in Mekong Delta. Green dots are light trap positions. Currently, 23 light traps have been established in Dong Thap.

| Light trap | 07/11/2011 | 08/11/2011 | 09/11/2011 | 10/11/2011 | 11/11/2011 | 12/11/2011 | 13/11/2011 |
|---|---|---|---|---|---|---|---|
| Sa Rài | 13 | 2 | 16 | 0 | 131 | 36 | No power |
| Tân Thành A | 85 | 78 | 93 | 325 | 11 | 1,250 | No power |
| Long Thuận | No power | 324 | 390 | 410 | 450 | 515 | 5,200 |

Figure 3. BPH data from some light traps in Dong Thap from 07/11/2011 – 13/11/2011

Figure 3 illustrates the number of BPH in three light traps in Dong Thap province. 'No power' means that there was no electricity in that night. The density of BPH in a light trap is calculated sorting by hand.

### *B. Saltwater intrusion*

Currently, the situation of drought and saltwater intrusion in the Mekong Delta are at an alarming rate and affect social life. In most estuaries and coastal areas of the Mekong Delta, saltwater encroaches on inland about 40-60 km, in 4-5 months [14]. Many provinces in the Mekong Delta get troubles with tap water. In a few regions, the situation is particularly serious: people do not have running water; therefore, it makes a great influence on the lives and health. On the other hand, farmers often use river water to irrigate their fields, vegetable gardens and fruit trees. Freshwater aquaculture is also a common industry in rural areas of the Mekong Delta. All these activities are very sensitive to salinity.

The first solution to confront saltwater intrusion is to regulate water in salt prevention sluice gates. Opening and closing the outlet of a sluice gate plays an important role which has a great impact on aquaculture activities as well as saline prevention solution of locals. Therefore, reasonable opening and closing outlet may protect the ecology system, ensure the locals life, and improve salinity intrusion in the dry season [15].

Another practice is plant choice restructuring to adapt to saline land. Some rice varieties adapting to saline land are now used. In addition, rice-prawn model has brought high economic efficiency and is contributing to structural economic shifts of the coastal provinces. Breeders continue research on breed salt-tolerant rice varieties that are suitable for current cultivation conditions and to overcome climate change in the Mekong Delta [15].

From 2012 to 2014, Can Tho Climate Change Office has been performing the project: *Improving the capacity to respond saltwater intrusion due to climate change in Can Tho city*. This project is to build a network of automatic salinity monitoring stations in Can Tho to immediately warn about saltwater intrusion. This leads to enhancement with quick warning about changes of the salinity in some main rivers in Can Tho. Besides, residents have access to saltwater intrusion situation easily and quickly by connecting to salinity warning SMS system [16].

### C. Floods

Every year, the Mekong delta faces with floods and their impacts. The term *flooding season* implies an annual basis from July to November in the Mekong Delta. In the past, the Mekong Delta had more than 10 big floods, occurring in 1937, 1961, 1966, 1978, 1984, 1991, 1994, 1996, 2000, 2001, 2002...[17]. Floods make a big damage to crops, livestock, and fisheries. For instance, in the flood 2012, about 27.000 hectares of rice crops were damaged; the area of industrial crops, fruit trees were flooded nearly 12.000 hectares; the total damage was estimated about 1,000 billion VND [18].

Governments and farmers in Mekong River delta have been constructing and maintaining dyke and embankment system surrounding their agricultural fields to control flood, and protect crops. Thanks to this system, two or three crop farms are annually cultivated in many places in Mekong River Delta. In 2008, there were approximately 1,000km$^2$ of three crop rice farms, 10,000km$^2$ of two crop and 1,300 km$^2$ of single crop farms [19].

In 2012, Southern Meteorological built and equipped 89 meteorological stations and 117 flood warning piles in order to create a system to monitor floods in the Mekong Delta. This system has operated since then. Stations have been installed with modern equipments to automatically collect data of rain water level. Next, data is transmitted instantaneously to Hydrometeorological Centre in province and Southern Hydrometeorology Station. This allows to process, compute, forecast fast and accurately some weather conditions such as tropical storms, floods [20].

Floods are not always negative. During the five month flooding period, 460 billion m$^3$ of water flowed through the delta each year, carrying some 200 million tones of alluvial, a mineral rich sediment that has high potential for soil enrichment. This type of flooding water also provides a nutrition source for fish and shrimp, while crops and livestock also benefits during flooding seasons. Flooding water can be regarded as a natural resource which local people can live with and take advantage of, even contribute to lessen the poverty rate in the region, thereby reducing the level of vulnerability to disasters [19].

### D. Water pollution

Water pollution causes significant economic losses in operations agricultural production and aquaculture. Aquaculture production (especially fish cage farming on the river) has been decreased due to river water pollution problems. For example, from 2/2012-3/2012, in Soc Trang, 30% tiger prawn died because of water pollution. In Tra Vinh, after the first month of the prawn crop 2012, almost prawns died in 600/6,000 hectares of aquaculture due to diseases [27].

Aquaculture has become a traditional craft and plays an important role for the national economy. However, aquaculture activities are sources of environmental pollutions on rivers in the Mekong Delta. In these activities, the main source of pollution is deposited-silt, which is wasted annually, in aquaculture ponds. In addition, in feed ingredients in aquaculture, only 17% dry weight of food is converted into biomass, the rest is discharged into the environment as manures or rotting organics. Another important problem comes from the industrial pond wastes. They are the source may cause environmental pollution and aquatic diseases in water [27].

Up to 2012, there were 61 industrial zones in Vietnam Mekong Delta, creating jobs for more than 70 thousand labors. Most industrial parks have been located along the Tien River and Hau River. The discharge of untreated waste water or non-standard processes cause environmental pollutants for these rivers [27].

To confront with water pollution, local governments in Vietnam Mekong Delta enhance monitoring agricultural activities and aquaculture in basins of Tien River and Hau River to closely control chemical pollutions in river basins due to fertilizer residues and chemical substances in plant protection [27].

## III. Architectures for Information Technologies

### A. Technologies

Information technology can help for controlling and understanding environmental behaviors, thanks to progresses achieved on size reduction for integrated circuits, radio communications, energy saving and harvesting. This section describes system organizations that are under investigation in projects of UCT, and the resulting service organizations.

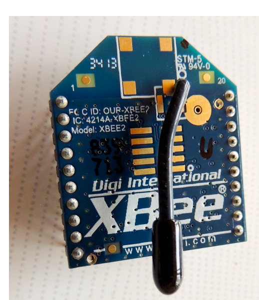

Figure 4. Radio module with pinout for serial control and data acquisition. Such modules can emit from few meters to kilometers depending on standards. They can fit Arduino boards

### *B. Sensor networks*

Sensors are used to connect information systems to the physical world. A basic sensor is a physic system that reacts to real world changes by producing current or voltage changes. These last changes can in turn be measured and transformed into digital values.

A common practice to interface sensors is to use Micro-controller units (MCU) that have Analog to digital converters (ADC) and other capabilities, then to connect these MCUs to sensors. Other possibilities include Smart sensors, where processing is done on the same circuit as data acquisition. Image processing is a good case for such devices.

Such "intelligent sensors" can help in local control, without interface to IT systems. However more and more of the sensing systems are now connected to register history of changes and to take into account surrounding contexts. By correlating histories together, by observing and computing relations between histories, research can build new knowledges, and warn the society on potential risks.

Interconnecting sensors together is now feasible at low price using radio communications. Resulting networks can work in different ways conforming to transmission and system standards.

As an example IEEE 802.15.4 standards define several frequencies (regional 700/800/900 Mhz and worldwide 2.4 Ghz bands), medium access control (MAC) protocol and network topologies usable for sensor systems: *star topologies*, or *peer to peer with possible mesh organization* [21]. Access to the medium can be achieved in different ways which includes *CSMA/CA* for random access, and *beacon based*, periodic access under control of coordinators. This last method is well suited to sensor networks having periodic sampling behaviour, since it takes care of sleeping periods, and provide a schedule for communications from *coordinators and superframes* (Figure 5).

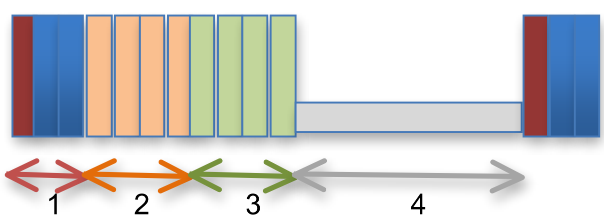


Figure 5. Superframe showing (1) beacon information, (2) slots with contention, (3) guaranteed communication slots, (4) sleeping time

Beside IEEE 802.15.4, other radio solutions exist, such as the use of cellular phone infrastructures, ZigBee and ISM variants (300-450Mhz).

Recent circuits from chip providers propose MCU, digital and analog interfaces, and radio transceiver on the same die, producing low cost solutions for sensor controls with protocol stacks. Radio modules and modular sensor boards allow to build swiftly sensor prototype systems and test new applications (Figure 4). Thus WSN have open the way to new control practice with impressive applications binding together thousands of sensors to save resources.

A WSN can also be an efficient tool to monitor and control the environment on a wider scale. Management of several problems of the Mekong Delta using this new technology is under investigation.

### *C. IT integration*

In sensor vocabulary, the *cover* is the part of the physical process in which the sensor can operate, collecting values. In practice, several physical interfaces to the real world can be associated to a system, therefore multiple covers can exist for one system. To give an example, light traps can attract insects to less than 10 meters, so their cover is at most this distance.

However, by sampling insects in several locations, and doing an interpolation between measures, a distribution of sensors can reflect the reality of a situation on large ground surfaces. By adding time labels to samples, it is also possible to appreciate how a situation is evolving with changes in densities and moves of an insect cloud.

The role of IT tools is to keep track of measures in the long term, and to propose synthesis through display and alert mechanisms to final users, farmers in the case of BPH.

Some requirements for integration are the following:

- a localization of sensors on geographic systems
- a modeling of the environment (sea, rivers, ...)
- the collection of data on sensors at given times, and probably given frequencies
- the computation of physical characteristics *inside the WSN*, necessary for runtime decisions
- a propagation of results and measure histories to gateways and external servers, answering queries
- the representation of the physical evolution on geographic systems or databases
- the analysis of measures and decision making

The geographic system data is critical for the layout of an observation system, the internal computations, and final interpretation.

To support these requirements and the simulations described in next section, a set of tools are developed.

**Map browsers**

This kind of tools is of common use to obtain geographical information as well as satellite pictures. A first implementation has been used to select geographic zone of interest; to specify sensor positions, to represent expected network connections, simulated or actual sensor values. The second generation browser produced swift moving and zooming over maps and access to several map databases, notably OpenStreetMap. They both have support for geographic localization.

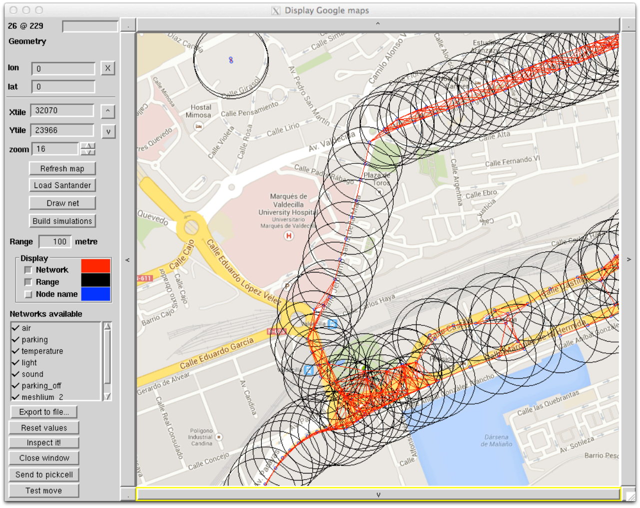


Figure 6. 1st generation browser displaying the Smart Santander european sensor experiment in real-time. 7 different networks are displayed which sensor connection range is tuned to 100meters. This browser is able to produce simulation architectures and to present data from simulation processes

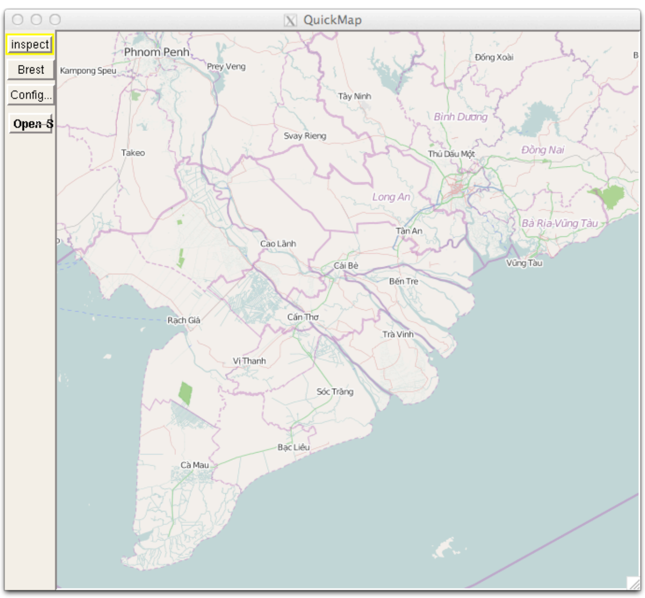


Figure 7. 2nd generation browser displaying map of the Mekong delta from OpenStreetMap data. The browser can move its display presentation at pixel level, under program control.

### Specifications of deployment: picking tools

These specifications are achieved on pictures rather than map systems. Both sensors layouts and mobile paths can be produced and expressed on abstract models.

### Image analysis

From the picking tools there is the possibility to produce layouts for geographic objects suitable for physical process simulation, running concurrently with network simulation. These tools consist of image segmentation and block classification according to min, max, mean in the RGB space. We expect to run physical simulation in various way, including cellular automata representing diffusions such as fires, insects, car traffic.

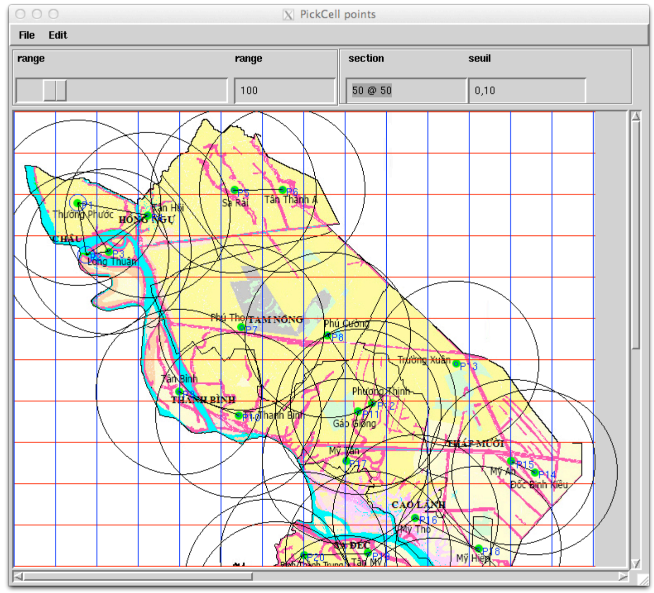


Figure 8. Sensor deployment preparation corresponding to current light-traps. The picture also shows a segmentation in 50 x 50 pixel blocks. Menu options allows to produce a graph model according to the selected range.

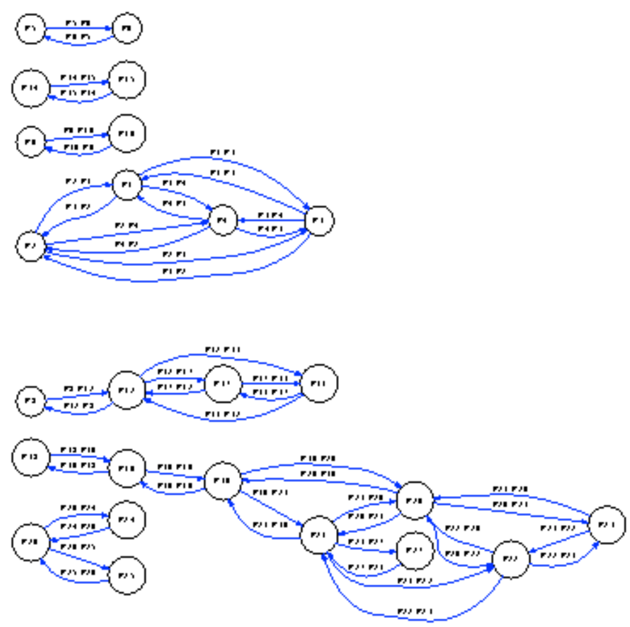

Figure 9. As the selected range is not large enough, the connections does not allow a completely connected network to be built. In this case, 7 networks appear in the logical graph. These graphs are traduction of the abstract model in *dot* file format for the *graphviz* program.

Figure 10 presents a layout extracted from the map. Each of the RGB component has been divided in 2 giving 8 cubes over the product of useful intervals for each color component. The *minimum* value in blocks was considered as classification criteria. By selecting the *mean* in these blocks, the 27 green spots for light-trap appear with very little noise as 5 additional block errors. Preparing such data partition can serve as a preparation of further physical simulations.

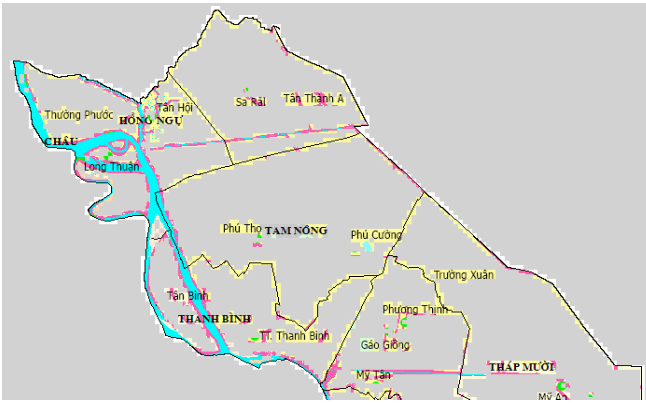


Figure 10. : Segmentation was operated according to 5x5 pixel grid. RGB cubes had been generated according to 2x2x2 partition. This is the map extraction corresponding to coordinates 0,1,3 for the minimum pixels in cells This map would allow to represent the river as an actor in a physical simulation.

## IV. Control Systems Design and Simulation

This set of tools is aggregated in the *NetGen* generic project names having a public documentation available on *github* [25]. NetGen is a flow for wireless sensor code simulation, and production (Figure 11).

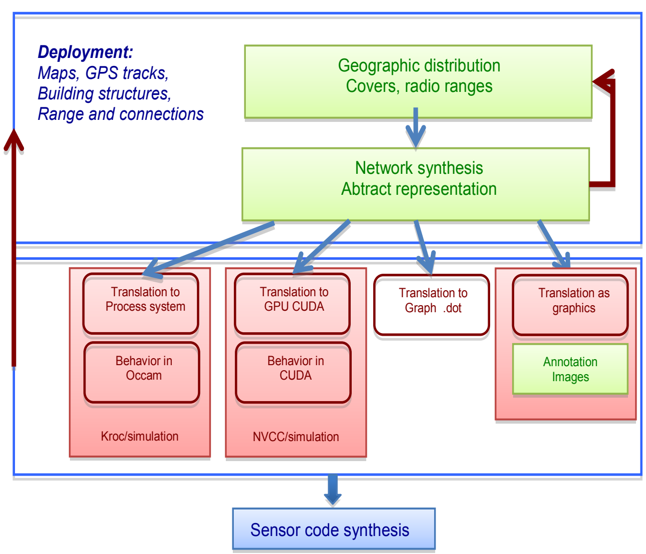


Figure 11. NetGen design flow showing 3 stages for sensor layout and network estimations, production of simulators, then reproduction of distributed code into actual sensor programs

### A. *Simulation code synthesis*

The role of simulations is to validate cooperative work inside the network. This is done by *distributed algorithms,* that compute local decision in group of sensors, that optimize the number of transfers according to network topology, that allows external devices to access data inside the network, building routing supports. Since these networks have a *dynamic nature*, it is very important to let them decide how to proceed [26]. Internal basic activities in network are achieved over the communication links, by procedures executed synchronously by nodes. As example:

- Diameter computation provides in each network the maximum number of steps necessary to propagate knowledge from each node to each other node.
- Leader computation provides a unique identifier in each network, plus a potential controller for various algorithms.
- Route computation provides in each node the capability to propagate packets on a shortest pat to any target.
- Local computations on bounded radius allow to get cumulated operations in the neighborhood.

These procedures also provide designers with estimation on cost of communications, delays, latencies, and casual risk of failures. They are fundamental for application design, in relation with the network architecture.

NetGen has two working translators from graphs to network representation, expressed as asynchronous process systems (Occam Language), or high performance synchronous execution on Graphic Processing Units (GPU, and CUDA tools), see Figure 11. Both of these translators cleanly separate *cooperative behavior*, and *architecture description*. The first one is a manual programming tasks, while the other is fully automatic, freeing the designer from practical issues management related to topologies. Refer to [25] for more details.

### B. *Estimation on Mekong Light trap system*

Simulation is run as a concurrent system of Occam processes that communicate over blocking channels. The periodic sampling shown Figure 4 is reproduced by having neighbor processes progressing synchronously in locked step fashion [26], thus simulation is strictly equivalent to what happens in real network.

When the *architecture description* is produced, a trace process is added to collect information from each simulated nodes. In this case, we have produced numbers for *leaders* and for *diameters.* The number of different *leaders* give the number of networks, while the *diameter* gives the number of useful hops inside networks.

| Range | 95 | 100 | 105 | 110 | 115 | 120 | 170 |
|---|---|---|---|---|---|---|---|
| Fan in | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| Fan out | 4 | 4 | 4 | 6 | 6 | 6 | 10 |
| channels | 48 | 50 | 58 | 70 | 78 | 84 | 142 |
| processes | 24 | 25 | 26 | 26 | 27 | 27 | 27 |
| networks | 7 | 7 | 6 | 3 | 2 | 2 | 1 |
| max diameter | 4 | 4 | 6 | 9 | 9 | 7 | 8 |

TABLE I. Static and dynamic information from simulation runs for ranges from 95 to 170. The 2 last rows are produced by the simulation in similar way as what happens in real case.

Notice that the first range embedding all sensor nodes is obtained for range = 115, and the first solution *fully* *connected* is obtained for range = 170, with a diameter of 8. This means that any algorithm willing to propagate values inside the resulting network will need 8 steps to proceed. The number of channels and maximum fan out represent the communication load on some node, with up to 10 neighbor inputs to handle. The choice of range = 120 can be better to save energy if it is feasible to join a common gateway from the two isolated networks.

To demonstrate neighborhood computations, we had developed and run a computation constrained by a radius (logical distance) around each node. The principle is an Occam program reproducing this algorithm:

- *Initially* each node set up a table *T* holding records *R* with *Id, distance, value.* The first entry is for the node itself, other entries are invalidated
- *For each step,*
  - nodes emit *T* and receive *Ti* tables to/from neighbors.
  - For each incoming table *Ti,* the table is swept and its contents is aggregated to *T, without duplicating entries for any Id*
- *After count step,* T is swept, computing a global value is produced (mean, global condition, sum)

The Table 2 displays the minimum and maximum count of neighbors on a *radius of 2* for each sensor in the previous networks. Notice that time stamps are also necessary to distinguish moment of measures, they can be deduced from the *distance* parameter in *R* records.

| Range | 95 | 100 | 105 | 110 | 115 | 120 | 170 |
|---|---|---|---|---|---|---|---|
| neighbor min | 2 | 2 | 2 | 2 | 3 | 3 | 5 |
| neighbor max | 8 | 8 | 8 | 11 | 12 | 14 | 20 |

TABLE II. MINIMUM AND MAXIMUM NUMBER OF NEIGHBORS (IDS) COMPUTED DYNAMICALLY FOR DONG THAP LIGHT TRAP SYSTEMS, RANGE FROM 95 TO 170

## V. CONCLUSION AND FINAL REMARKS

In this paper, WSN has been used as an information technology tool to monitor some environmental conditions in Vietnam Mekong Delta. These conditions may come from some threats such as pest insects, saltwater intrusion, floods, water pollution; which may endanger to food in Mekong Delta.

Pest insects threat with light trap solution is focused in this paper. We simulate several WSN options for light traps network in Dong Thap province in the Mekong Delta using NetGen. The network range 170 is fully connected, meanwhile, the transmission range is large enough to cover all sensor nodes leading to a single well balanced network. However, the choice of range 120 is more energy saving if we can use a common gateway for the two isolated networks.

WSN can be used to face with remaining threats. For example, sensors can be used to collect the water pollution data in rivers in Mekong Delta. This data is useful for aquaculture households in Mekong Delta. Another usage of sensors is to monitor salinity in rivers to immediately warn about saltwater intrusion. They can be en efficient tool to monitor floods as well.

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