SNDT:a genetic algorithm-based Sensor Network Design Tool

Jin. Fan   Prof. D.J. Parish

High Speed Networks Research Group, Loughborough University

10th July, 2009

Design Challenges

- Application-specific Architecture
- Resources are significantly limited

Design Challenges

- Application-specific Architecture
- Resources are significantly limited

Motivation

- The decision to select a good set of protocols for a given task before a WSNs practical deployment is an important issue.
- Simplyfy the design procedure to allow more unspecialized users.

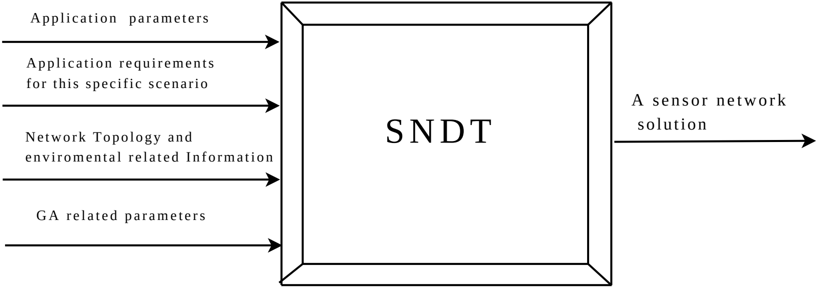
A system which can offer a good solutions based on expert knowledge and can be easily used is strongly desired by a wider audience of users.

Motivation

- The decision to select a good set of protocols for a given task before a WSNs practical deployment is an important issue.
- Simplyfy the design procedure to allow more unspecialized users.

  A system which can offer a good solutions based on expert knowledge and can be easily used is strongly desired by a wider audience of users.

Global Input and Output



Challenges for SNDT

Challenges

- Performance evaluation system
- Optimization techniques
- Find one fair simulation tool to execute the experiment

Assessment of a WSN

How do we evaluate the WSN performance under different protocols configurations?

Objectives	Optimization parameters	Performance measures
M1	One-way delay	OWD
M2	Loss	LSS
M3	Time when first node died	TFD
M4	Time when half nodes died	THD
M5	Energy consumption per useful bit	EPUB

Table: Metrics used when assessing the performance of a WSN

Performance function

Given the metrics we consider, a linear weighting function measures the quality and the performance of a WSN design is derived.

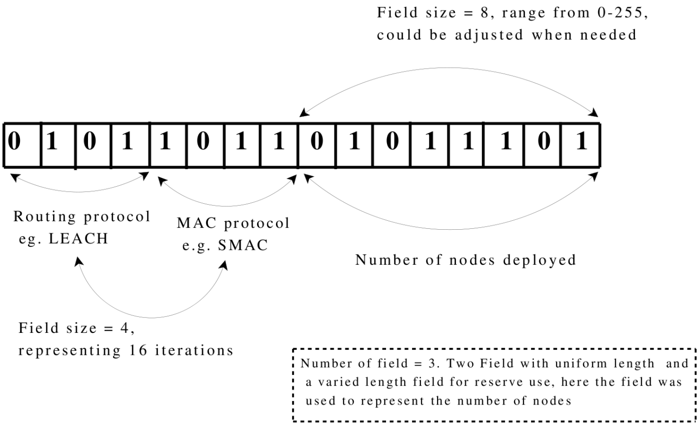
$$f_{performance}(X) = W * M(X) \tag{1}$$

$$\begin{aligned} f_{performance}(X) &= \sum_{i=1}^{5} w_i * M_i \\ &= w_{OWD} * OWD(X) + w_{LSS} * LSS(X) \\ &\quad + w_{TFD} * TFD(X) + w_{THD} * THD(X) \\ &\quad + w_{EPUB} * EPUB(X) \end{aligned}$$

Apply a GA into our problem

- Problem representation
- The formulation of the fitness function
- The choice of the genetic operators and the selection mechanism

an example of a Chromosome Structure



Fitness function

Importance coefficiencts A are introduced to eliminate the difference in the scale of different performance metric.

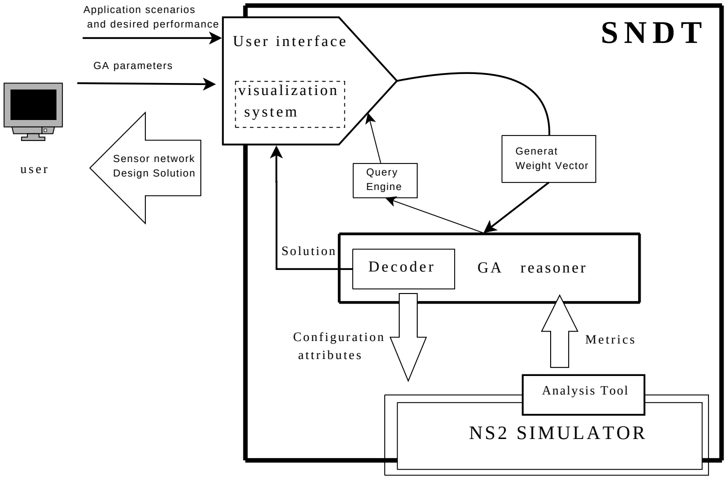
$$f_{fitness}(X) = \frac{1}{A \times f_{performance}(X)} \quad (2)$$

$$f_{fitness}(X) = \frac{1}{\sum_{i=1}^{5} \alpha_i * w_i * M_i} \quad (3)$$

Genetic operators and selection mechanism

- The one-point crossover, applied with some specific probabilty p_c.
- the classical mutation for binary representation, which swaps bits of each string (0 becomes 1 and vice versa) with a specific low probability p_m .

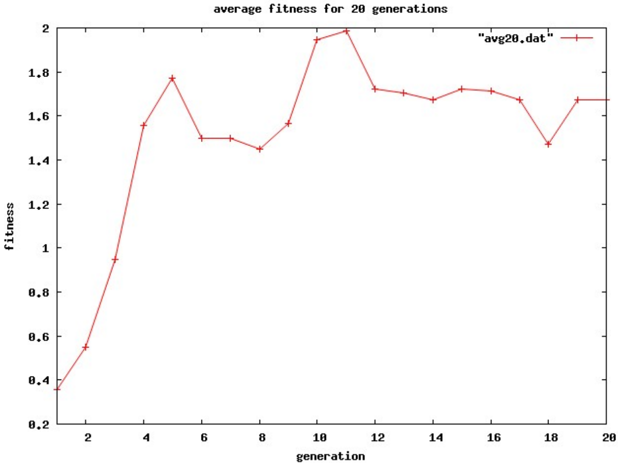
System components



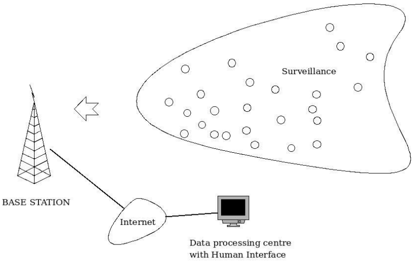
GA related challenges

- Population Size is determined to 10
- The probabilities of crossover and mutation are identified as 0.8 and 0.008 respectively
- The type of crossover and mutation

The evolution progress in SNDT



Emergence Detection



- Respond to an emergence as soon as possible
- keep active just as long as the event detected

System Input for an Emergence Detection scenario

Table 7.2: Inputs of SNDT for a Fire Detection scenario

Application related	Traffic type	Poisson
	PacketSize	100bytes
	Packet Interval	$5s$
	Data Duration	$100s$
Target area Information	Topology	Randomly distributed
	Area range	$100m * 100m$
Performance requirements	One-way Delay	w_{OWD}=0.2
	Loss	w_{LSS}=0.3
	Time of first node died	w_{TFD}= 0.1
	Time of half nodes died	w_{HFD}= 0.1
	Energy consumption per useful bit	w_{EPUB} =0.3
GA related parameters	Population size	10
	Selection Mechanism	Stochastic Sampling
	Crossover Method	One-point Crossover
	Crossover Rate	0.8
	Mutation Method	Swap bits of each string following the p_m
	Mutation Rate	0.008

System Output

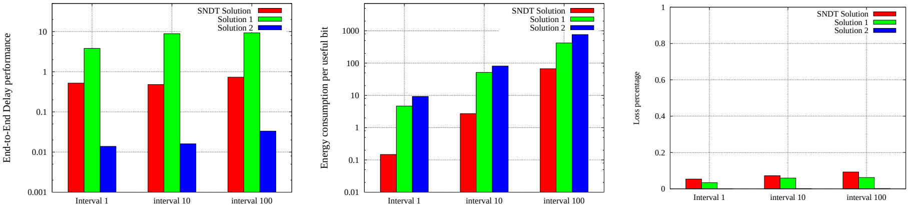
```
                              Population Report
Generation   19                                                    Generation   20
num   string               fitness    parents xsite  string                fitness
--------------------------------------------------------------------------
  1)  1001110101101001  11.442191 | ( 4, 8)   10   1111110111101000  10.701533
  2)  1110010101101000  5.710451 | ( 4, 8)   10   1011110011101001  27.517066
  3)  1110110111110000  10.598362 | ( 6, 5)   11   1011100111101000  10.701533
  4)  1111110111101001  12.330057 | ( 6, 5)   11   1111110111001010  4.343776
  5)  1111110111101001  12.330057 | ( 8, 9)    3   1011110111101000  10.701533
  6)  1111110111101000  10.701533 | ( 8, 9)    3   1111110110101000  9.202719
  7)  1111110001101000  0.669650 | ( 6, 1)    5   1111110101101000  5.710451
  8)  1011110111101000  10.701533 | ( 6, 1)    5   0011010101111000  15.961278
  9)  1111110111101000  10.701533 | ( 8, 2)    1   1110010101101011  3.401236
 10)  1111100111101000  10.701533 | ( 8, 2)    1   0011110111101000  10.701533
--------------------------------------------------------------------------
Generation 20 Accumulated Statistics:
Total Crossovers = 12, Total Mutations = 45
min = 3.401236   max = 27.517066   avg = 10.894266   sum = 108.942659
Global Best Individual so far, Generation 17:
Fitness = 38.203200: 1000110000011100
--------------------------------------------------------------------------
```

Comparing SNDT solution with other two empirical solutions

Solution	Routing protocol	MAC protocol	number of nodes
Solution 1	AODV	TDMA	100
Solution 2	DSR	IEEE802.11	100
SNDT Solution	DSR	SMAC	56

Performance Comparision

The performance of each networking solution is assessed with the End-to-End delay, loss and EPUB.



Conclusion and future work

Conclusion

- SNDT is proposed to optimize a WSN design
- The design progress is based on the evolutionary optimization procedure of Genetic Algorithms.
- A well-informed performance function considering network connectivity, application-specific requirements and energy conservation, is derived to measure a WSN operation

Future work

- test it under different application scenarios
- Other configuration attributes such as error handling mechanisms, environmental effects will be considered

Thank you

Questions?

Wireless sensor networks simulation software

Simulator	Simulation model	Languages	Description
NS2[83]	ISO/OSI	OTCL, C++(Object-oriented)	Include huge number of protocols, traffic generators and tools to simulate TCP, routing, and multicast protocols over wired and wireless.
NRLs sensor extension to NS-2	ISO/OS	OTCL, C++(Object-oriented)	modeling the presence of phenomena transmitted through a designated channel in NS2[84].
TOSSIM	At bit level	NesC[85]	Simulates TinyOS motes
SENSE	ISO/OSI	C++ (component-port model)	Offers different battery models, simple network and application layers, and a IEEE 802.11 implementation.
GloMoSiM	ISO/OSI	C/Parsec	Standard API used between the different simulation layers. The simulation is built on top of Parsec
OpNet	ISO/OSI	C/C++	Provides a simulation language with network libraries
Matlab	-	M-code	Numerical computing viroment. Allows easy matrix manipulating,implementation of algorithms etc..

Protocols considered in current SDNT