On-line self-diagnosis based on power measurement for a wireless sensor node

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Outline

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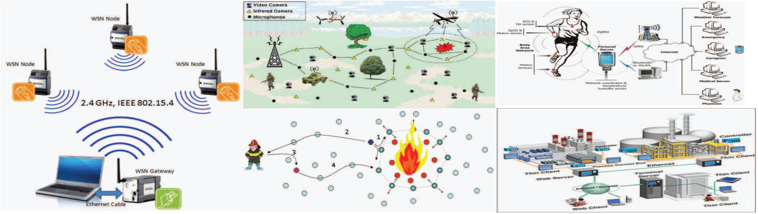
Application fields of WSN

Advantages

- Easy deployment.
- Self-organisation.
- Reconfigurability.
- Portability.
- Low cost.

Application fields

- Area and Environment monitoring.
- Health monitoring.
- Home automation.
- Industrial monitoring.
- Military monitoring.



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- Element is down due to ***hard-failure***.

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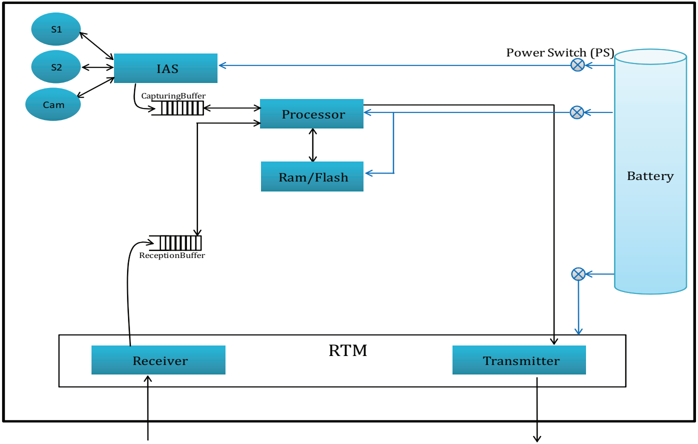
Objectives

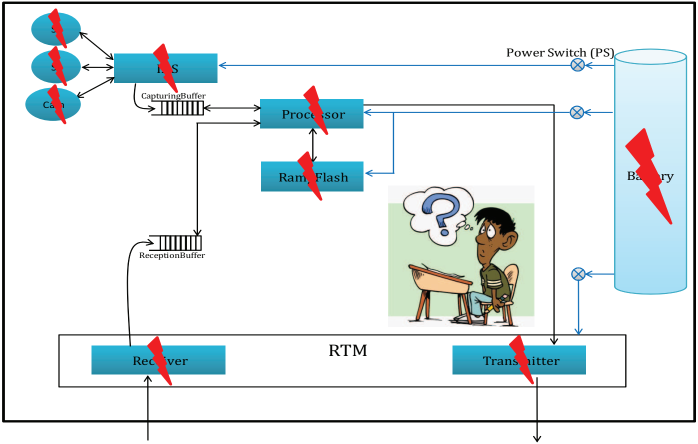
To propose an on-line self-diagnosis that can detect and localize the failing element of wireless sensor node.

Hardware configuration of wireless sensor node



IAS : *Interface of Actuator and Sensor* **RTM** : *Radio Transceiver Module*

Hardware configuration of wireless sensor node



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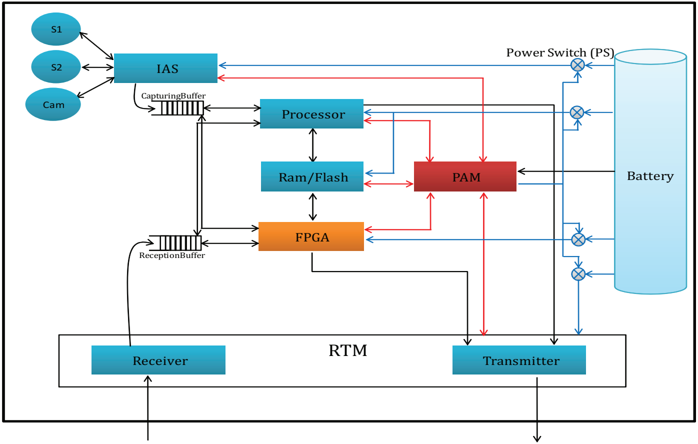


IAS : *Interface of Actuator and Sensor*
PAM : *Power Availability Manager*
RTM : *Radio Transceiver Module*

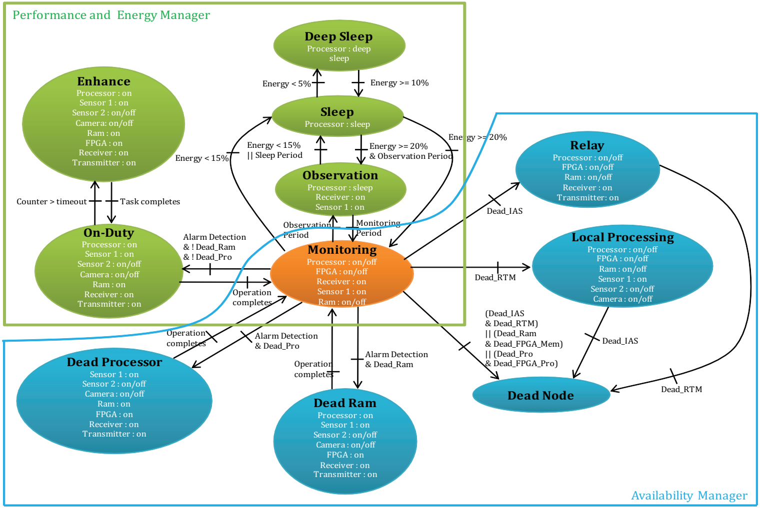
Issues and Corrective Solutions

The complementary devices are added in sensor node :

- **PAM Block** is considered as intelligent part to reduce energy consumption and react against the issues.
- **FPGA** enhances availability and performance for sensor node.

Issues	Software and Hardware causes					Energy causes		Solutions
	Dead Processor	Dead Ram	Dead IAS	Dead RTM	Software Bugs	Low Energy	Energy depletion	
Dead Node	X							PAM enables FPGA processor to replace main processor
		X						PAM enables FPGA memory to replace RAM/Flash memory
							X	Wait for recharging battery
Malfunctioning Node			X					PAM changes mode of operation to relay point
				X				PAM changes mode of operation to local processing
					X			Processor reboots
						X		PAM selects consistent mode of operation and waits for battery recharge

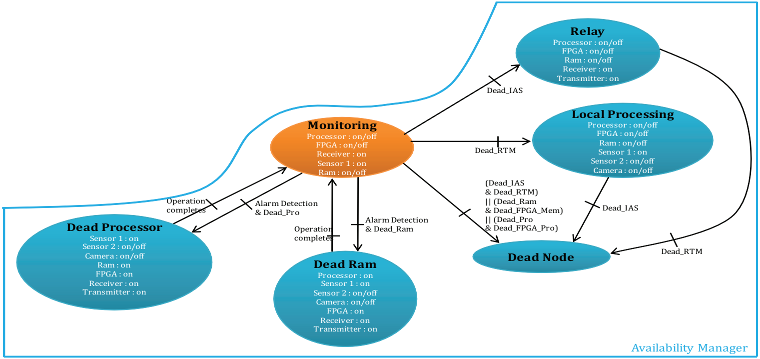
FSM model for mode modeling



FSM model for mode modeling

Definition

Availability is the ability of an entity to be able to accomplish a required function under given conditions and at a given time.



Outline

1. Background
2. Our approach for on-line self-diagnosis
   - Failure detection
   - Failure localization
3. Simulation
4. Conclusions and Perspectives

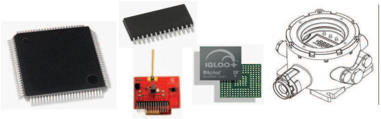
On-line self-diagnosis

On-line self-diagnosis is applied to :

- Detect hard-failure based on power consumption.
- Then localize correctly the failing element in order to take an appropriate corrective solution.

Failure detection based on power consumption

The application of hazardous gas detection for area such as harbor or warehouse is used to illustrated our failure detection method



Element	Power (mW)
PIC24FJ256GB110	36
M48T35AV memory	150
Oldham OLCT 80	867
Miwi Radio transmitter	130
Miwi Radio receiver	70
Core8051s	26
PAM block	0.1

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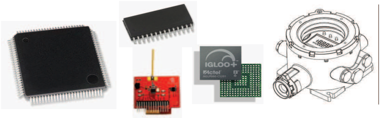

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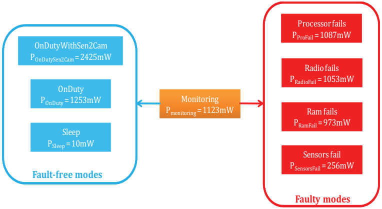
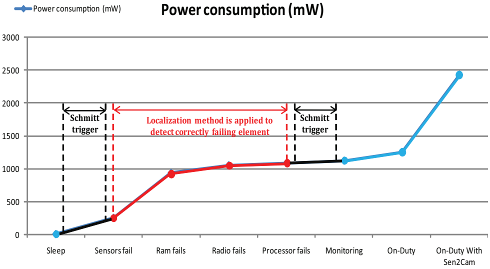
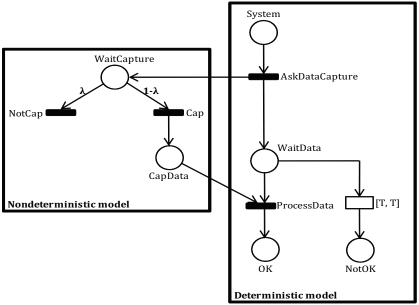




Petri Net modelling for discrete-event systems

Definition

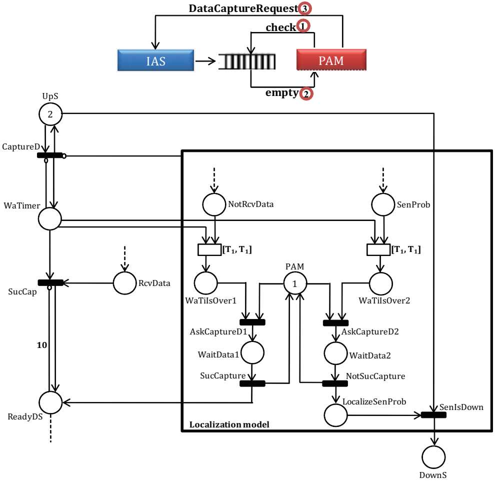
A *Timed Stochastic Petri Net graph* (TSPN) is a weighted bipartite graph (P, T, A, w, Ti, Pb), where : *P* is the finite set of places, *T* is the finite set of transitions, *A* is the set of arcs from places to transitions or from transtions to places, *w* is the set of the multiplicities of the arcs, *Ti* is the set of the firing times of the transitions, *Pb* is the set of the firing rates of the transitions.



Failure localization for sensor

A functional test is applied to check the state of sensor as follows :

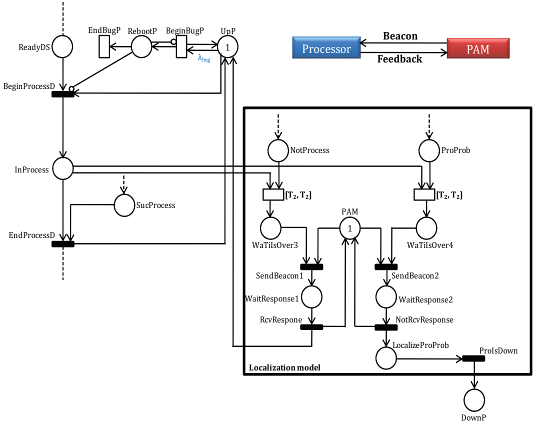
- Check the state of capturing buffer.
- Make a request of capturing data if capturing buffer is still empty during a time interval T_2.
- If data arrive into capturing buffer, sensor is still available. Otherwise it is down.



Failure localization for processor

A functional test is applied to check the state of processor as follows :

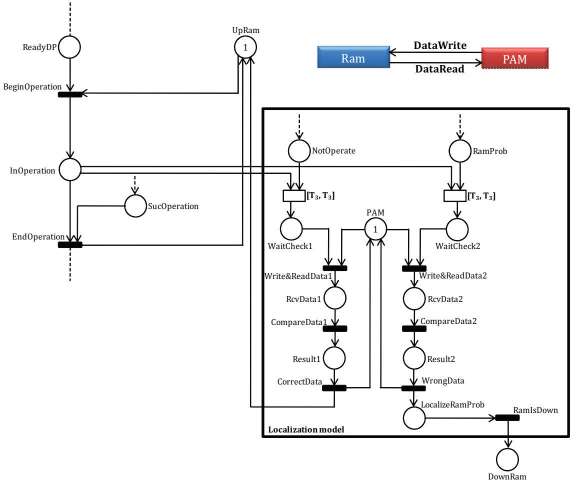
- The PAM block sends a beacon signal to processor and wait its response.
- If our PAM does not receive any feedback from the processor, the processor is considered as failed.



Failure localization for RAM memory

A functional test is applied to check the state of RAM as follows :

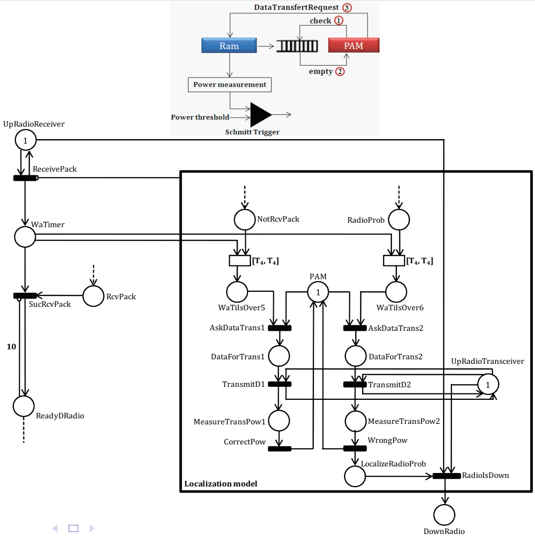
- To check the availability of RAM memory, the PAM block writes a testing data of 32bits in an address of memory space.
- Then, PAM reads the writing data at the same address.
- The reading data is compared with the the original data. If they are similar, Ram memory is still available, otherwise it is down.



Failure localization for Radio module

A functional test combined with physical test is applied to check the availability of radio module as follows :

- Check the state of reception buffer.
- Make a request of data transmission to a neighbor node if this buffer is still empty during a time interval T_4. This step is called as the ***functional test***.
- The transmission power is measured by an embedded electronic device, and then is compared to a power threshold using a Schmitt trigger. If the output result of this trigger is true, the radio is still available, otherwise it is down. This step is called as the ***physical test***.



Outline

Introduction of simulation tools

In our approach, two different constraints of availability and energy are simulated by two different tools.

1 Capnet-PE tool for energy simulation

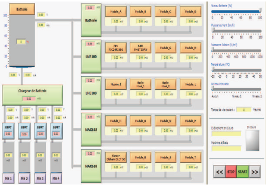
CAPNET-PE tool is created by Nicolas Ferry and al. at Lab-STICC laboratory, in the project with Eryma company.

This tool allows to :

-) Predict the node autonomy.

-) Provide energy consumption of node based on business scenario.

-) Predict energy harvested from the environment based on the weather forecast.



Capnet-PE tool for estimating energy consumption

2 SPNP tool for availability simulation

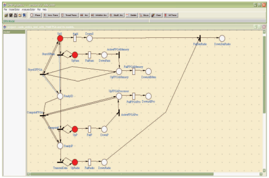
This tool is created by Prof. Kishor S. Trivedi and al. at Duke University in Durham NC, USA.

This tool allows to :

-) Model the node system using Petri Net.

-) Perform the concurrent operations and asynchronous events of node system.

-) Provide the failure prediction features.



SPNP tool for modeling node system

Mean Time To Failure

Definition

Mean Time To Failure (MTTF) is defined for non-repairable systems to indicate the average functioning time from instance 0 to the first appearance of failure.

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Component	Failure rate (λ)	MTTF
Sensor	1/30000 $hour^{-1}$	3.4 years
Processor	1/262800 $hour^{-1}$	30 years
RAM	1/83220 $hour^{-1}$	9.5 years
RTM	1/100000 $hour^{-1}$	11.4 years
FPGA memory	1/80000 $hour^{-1}$	9.1 years
FPGA processor	1/131400 $hour^{-1}$	15 years

The availability of each element is given by :

$$R(t) = e^{-\int_0^t \lambda(x)\,\mathrm{d}x} = e^{-\lambda . t} = A(t) \qquad (1)$$

The failure probability of each element is given by :

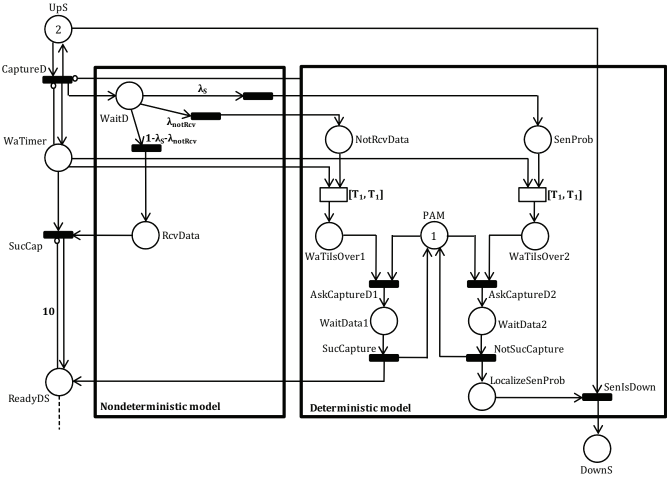
$$F_{sensors} = (1 - A_{sensor1}) * (1 - A_{sensor2}) \qquad (2)$$

$$F_{processor} = 1 - A_{processor} \qquad (3)$$

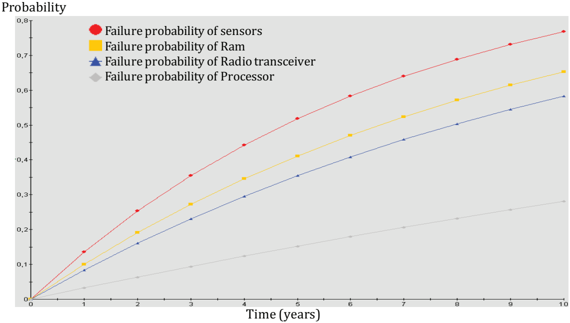
$$F_{ram} = 1 - A_{ram} \qquad (4)$$

$$F_{radio} = 1 - A_{radio} \qquad (5)$$

Failure localization model for sensor node



Failure Probability of each element



Remark

- The obtained curves are consistent to the above equations of computation of failure probability.
- The sensors are the most critical elements due to their low reliability (the smallest MTTF), because their circuitry is very complex.
- This simulation result allows to validate our localization method of failing element.

Energy results

The consumption of wireless sensor node is simulated with the application of detection of hazardous gaz using Capnet-PE tool during seven days.

Elements	Energy 1(J)
Ram memory	5510
Processor	7203
Radio	7630
Gas sensor 1	16124
Gas sensor 2	523
Camera	71
FPGA Core8051s	6.1
FPGA PAM block	1.94

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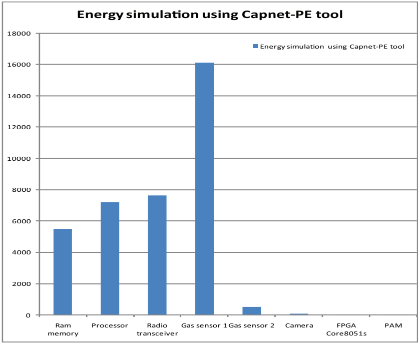

Remark

The consumptions of PAM block and FPGA Core8051s are very small compared to other node elements.

Outline

Conclusions and perspectives

Conclusions :
A on-line self-diagnosis is proposed for wireless sensor node with its efficient implementation in term of energy that can :

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Perspectives :

- Implement our approach in real material for evaluating.
- Measure the energy overhead when using the additional electronic devices for power measurement.

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Thank for your attention !

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