IJCTA, 10(02), 2017, pp. 119-123

Implementation of Wireless Sensor Network based Multi-core Embedded System for Smart City

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Abstract : Embedded Wireless Sensor Networks are used for immense applications and at the same time, present several challenges. In certain application scenarios like an army, supervision and traversing, and smart environments where hundreds or even thousands of sensor nodes are spread out and requires complex refinement of data, which would reduce the lifetime of the network. This could be overcome by Multi-Core system based Wireless Sensor Networks. The objective of this paper is to develop a multi-core embedded wireless sensor network for smart city application. The smart city application includes traffic profusion, environment monitoring, intelligent roads and garbage management. The hierarchical architecture comprising of the group of leaf nodes forming a cluster node and sink node with wifi communication is implemented and tested.

Keywords : Wireless Sensor networks, multi-core, smart city, hierarchical architecture.

1. INTRODUCTION

Wireless Sensor Networks (WSNs) comprises a vast number of sensor nodes with embedded sensors for monitoring the physical parameters of the environment and each sensor nodes communicate with several other nodes and/or sink node over the wireless network [1], [10]. Each sensor nodes perform three primary functions of sensing the data from external surroundings, processing the sensed data and communication. The potential fields of applications supported by wireless sensor networks are tremendous and at the same time it offers several challenges predominantly the energy constraints, the lifespan of the sensor nodes, computational strain and communicational difficulties [2].

Several research activities have been carried out and many techniques were improved in sensor networks for aggregation of obtained information and data collection from several nodes in the network in order to lessen the communication cost, to beat the energy constraints and to maximize the durability of sensor nodes [3], [4], [5].

Excluding the above-mentioned challenges, there remain further challenges in the network. A few among them are sensor fusion, construction, and deployment of sensor nodes, routing and scheduling. The researchers started computational intelligence method to address it. On the other hand, the proposed computational intelligence algorithms were barely noticeable and few lie in the progressing stage. Efforts are carried to promote the existing work and to meet the requirements of sensor networks [6].

Despite various techniques adopted to overcome the challenges of wireless sensor networks where the sensor nodes are dealing with smooth sensor data, in certain other applications where in-depth details [*e.g.*, from video sensor] and complicated information refinement is required, the sensor nodes endure

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from power consumption that tends to cut-off the lifespan of the network and so disturbing the data greedy applications [1], [7]. This could be overthrown by multi-core nodes in the sensor networks [1] which demand complicated processing of the sensed information and suffering from power consumptions. One such application is Smart City. This paper deals with the design of multi-core embedded wireless sensor networks for smart city application.

2. MULTI-CORE IN SENSOR NODES

After the launch of multi-core technology, many embedded systems transit from the single core processor to many-core processor. Multi-core systems are an intrinsic part of present day embedded systems which allow for enriched performance and decreased power loss. A little effort to maximize the lifespan of wireless sensor networks is appreciable. The researchers directed to exercise the benefits of multi-core systems in wireless sensor networks. The multi-core processor in sensor networks provides enormous benefits and aid in overcoming several computing challenges in various complicating applications. A few of them are listed beneath:

1. It was found that multi-core CPU could help to manipulate the hard real-time tasks without missing their time limit, by partitioning the different tasks amidst several cores [8].
2. The results reveal that 76% power loss can be lessened by using triplet core instead of unique core amidst sensor nodes [8].
3. The multi-core sensor nodes could be used in wireless sensor networks (WSNs) that demand complicated information processing gained from the sensors [1].

Architecture for multi-core embedded wireless sensor networks (MCEWSNs) was proposed by the authors. The proposed architecture for MCEWSNs [1] considering data greedy and complicated processing applications is shown in fig.1.

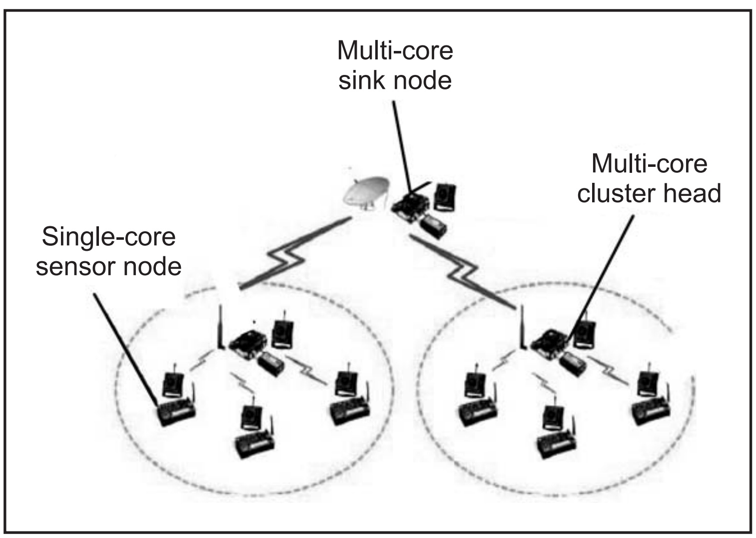

Figure 1: Architecture for multi-core embedded wireless sensor networks (MCEWSNs)

3. PROPOSED METHODOLOGY

This paper deals with the design of multi-core embedded wireless sensor networks for smart city application. While considering the smart city, it includes various features where hundreds or even thousands of sensor nodes are deployed in a city and demands immense data from the sensing devices and also communication technology for smartness. To exercise the benefits of multi-core technology for achieving economic and efficient performance and also to lengthen the lifespan of the sensor networks, multi-core based sensor nodes are used in the application.

In this paper, the smart city based on Multi-Core Embedded Wireless Sensor Networks includes features like:

1. Prior notification of traffic blockage for the upcoming routes in the case of accidents or bottlenecks, to the people which could aid in taking the surrogate routes.
2. Keeping track of environmental weather circumstances and displayed a warning message that benefits the people to have prearranged journey and also in taking the surrogate path.
3. Air deterioration fumes from factories, transportation, and thermal stations in a city are detected and maintained in the database to oversee and survey.
4. Sewage levels in different containers across the city are monitored against outset limit and saved in the database to amend collection routes.

Architecture for smart city application based on wireless sensor networks involving multi-core nodes are shown in fig.2.The architecture is hierarchical [1] with leaf nodes designed using Arduino Uno controller (single-core) with wifi communication. The leaf sensor nodes are properly deployed for weather monitoring, traffic profusion detection in the case of accidents/overcrowding, air fumes measuring, and garbage measurement. The data from several leaf nodes are carried to the cluster node over wireless link using wifi module ESP8266. The cluster node consists of the single or multi-core sensor nodes. In this paper ARM LPC 2148 (single core) were used to obtain the sensed information from the leaf nodes. Finally, the sink node is designed using Raspberry *pi* 3 (quad core ARMv8) where each core is assigned the separate task to achieve the application features.

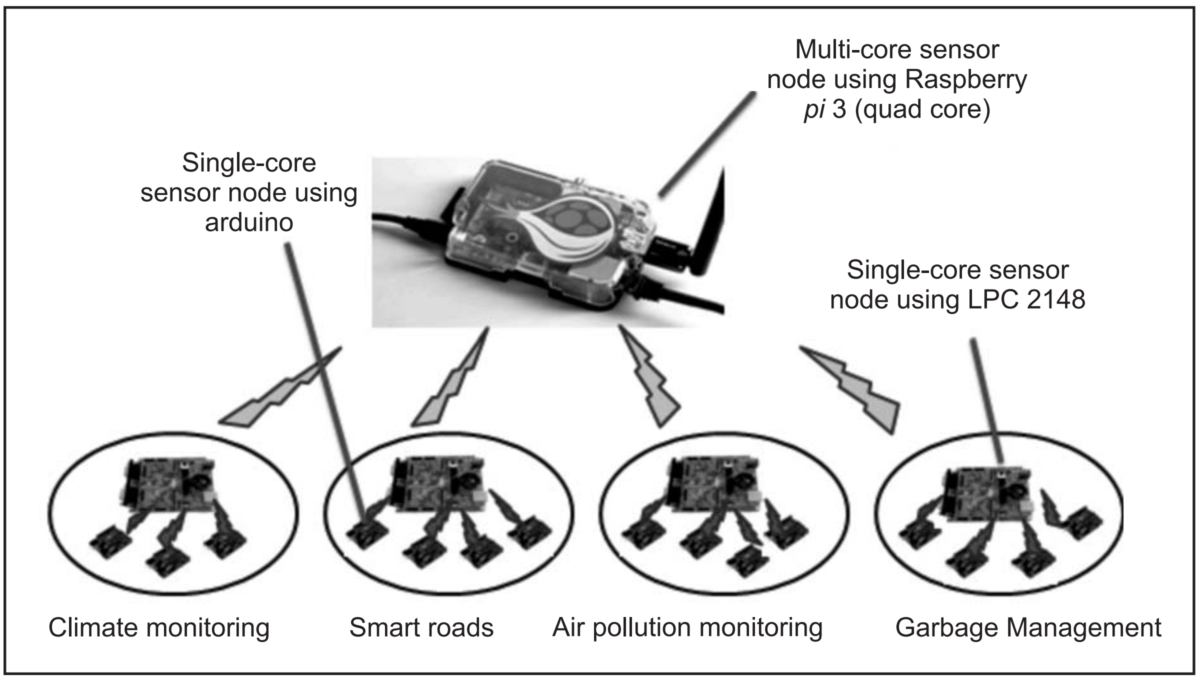

Figure 2: Smart city features implemented using Multi-Core Embedded Wireless Sensor Networks

4. IMPLEMENTATION DETAILS

A. Leaf Sensor Nodes

1. **Climate Monitoring :** To monitor the weather conditions two sensor modules are used. One is temperature sensor LM35 whose output voltage relates to the temperature in centigrade. Another module is rain sensor module whose output voltage provides the information to infer the amount of rainfall like heavy, moderate or light rainfall. The dual sensors are interfaced with Arduino Uno controller to predict the weather conditions. The predicted data is sent to the cluster node. It displays the climate of other leaf nodes in the network based on commanding information from

the sink node via cluster head node. It could aid the driver in taking the surrogate paths depending on climatic conditions. The block diagram is shown in fig. 3.

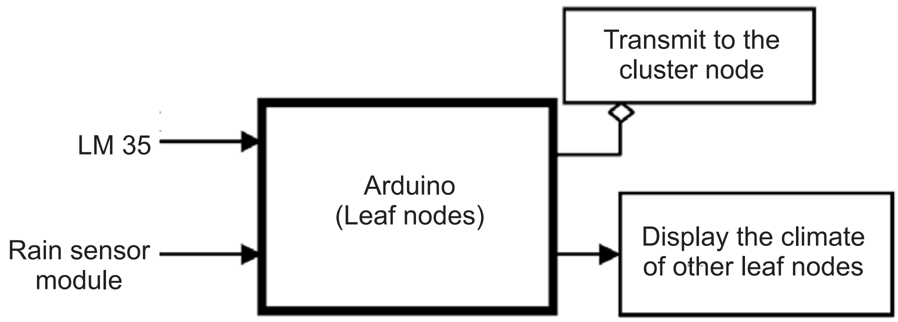

Figure 3: Climate monitoring system in the leaf nodes

2. **Smart Roads :** In the case of traffic bottleneck due to accidents/overcrowding, notification message need to be displayed to the user regarding the upcoming routes, so that the driver could take some surrogate routes. The traffic density information could be obtained using the technologies adopted for sensing the traffic [9]. The Arduino Uno process the information obtained from the sensors. The block diagram is shown in fig. 4.

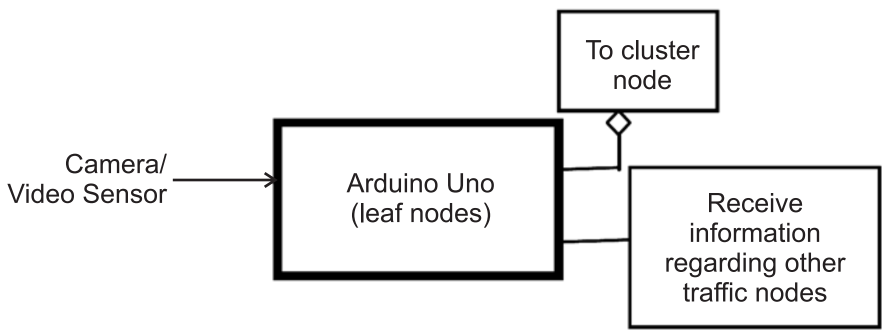

Figure 4: Smart roads

3. **Air Deterioration Fumes Detection :** To achieve smartness in the environment various air deterioration fumes are measured from factories, transportation, and thermal stations. The air gas sensors shown in fig. 5 are used to measure CO2, CO, NOx, SO2 and various other gases. The sensors are interfaced to the Arduino Uno controller and measured its quantity in ppm and sent to the cluster node.

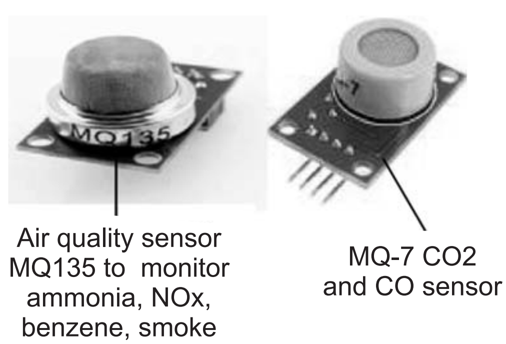

Figure 5: Air quality measurement sensors

4. **Garbage Measurement :** The wastage level in the container is measured using load cell and indication message with the address details are sent whenever the amount exceeds the outset limits. The load cell sensor is interfaced with Arduino Uno controller and sewage level is measured and transmitted to the cluster node if the detected level exceeds the threshold limits.

B. Cluster Node and Sink Node

The sensed information from the leaf sensor nodes is carried to the cluster nodes. The cluster node is designed using ARM LPC 2148 (single-core) with wifi module. The cluster node could also be designed using multi-core systems. In the case of the single core, the entire leaf nodes from a single network are connected to the cluster head processor. Whereas in multi-core cluster sensor nodes, the leaf nodes could be divide into small groups and each group is assigned to the different cores in the multi-core systems [1].

The different cluster heads are connected to the sink node over the wireless network. The sink node is constructed with quad-core Raspberry *pi* 3. The application attributes are partitioned among several cores in the Raspberry pi 3 and implemented. The functionality of different cores is listed in table 1.

Table 1
functions of different cores in the raspberry *pi* 3

Cores	*Functions*
Core 1	Responsible for decision making to display the climatic conditions in proper routes that could aid in taking the alternative paths and also store the climate data on website for access from anywhere in the city.
Core 2	Takes care of displaying the traffic congestion information in various routes.
Core 3	Store the air pollution data from several locations in the database to accomplish control action in future.
Core 4	Store the garbage level in the database obtained from cluster head node to notify the municipal authorities regarding the need for sewage disposal in a location.

5. CONCLUSION

Smart city attracts the urban residents for upgrading their life comforts. To achieve smartness in the city, it required immense data and numerous processing which directed to utilize the multi-core based system for sensor nodes in the wireless sensor network. The multi-core sensor nodes for smart city application are implemented with wireless sensor networks.

6. REFERENCES

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