Applications of NANO-RK in Internet of Things (IoT)

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APPLICATIONS OF NANO-RK IN INTERNET OF THINGS (IoT)

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Abstract – The IoT is famously known as Internet of Things is a universal communication for everything can communicate with Internet sensors. The sensors devices are designed as constrained, lightweight, minimum energy powered and capacity of minimum battery life run by Real-time operating systems[6]. The Carnegie Mellon University designed micro controllers for sensor networks. NANO-RK is one of the open source Real-time operating system for to run real-time tasks. The NANO-RK operating system, the term RK is short for resource kernel. A resource kernel provides reservations on how often system resources can be consumed and managed. For example, Using NANO-RK, by applying to set CPU resource reservations technology, a task might only be allowed to execute 10 ms every 150 ms.. In the same way another example by using Nano-Rk by applying Network resource reservations technology a node might only be allowed to transmit 10 network packets per minute. The applying these reservations to protect battery life of a node and also protecting a failed node from generating excessive messages in network traffic. For this, the battery life of a node will be minimized. The NANO-RK is open source and written in C language and runs on the Atmel-based FireFly sensor networking platform. The goal of this paper is an overview of NANO-RK. As per operating system capabilities and also takes part from an open source of ecosystem facilities, the NANO-RK is the a suitable operating system for constrained and lower power sensor devices for Internet of Things. In this paper, the study of the most important features of IOT based Resource Reservation, Deep sleep mode, Fault management and Routing features by NANO-RK operating system[3].

Keywords – IoT, Nano-Rk, ROT, microcontroller, resource reservation, deep sleep mode

I. INTRODUCTION

The Internet is expanding with the advent of the Internet of Things (IoT)—billions of physical entities on our planet (and beyond) are expected to be instrumented and interconnected by open protocol standards. In particular, the IoT will harness next-generation sensors and actuators to interoperate with the physical world. Such cyber-physical systems will not only perform data acquisition and processing, but are also likely to control more and more elements of our environment. IoT devices will not only interconnect, but also extend communication beyond gateways, into today's Internet (e.g., the cloud) which has not dealt before with so many devices of marginal intelligence[2].

Every thing in the universe is going to be connect to the Internet for managing the things. i.e. the scope of communication by M2M rather than H2M[4]. The human invention of things like Machines, Internet and communications are become to M2M interaction for that Internet of Things becomes Every Thing of Internet[4,5]. The architecture of IOT designed with a specialized communication of open standard protocols. The design of architecture and layers of IoT implementing such as the things which are connected, communicated and managed by specialized protocols.

In terms of hardware resources, the IOT devices are very constrained, they are having minimum energy resources, battery life very low so these are not yet all capability having enough resources to run traditional operating systems like Windows, Linux and BSD. As per resource limitations of these IoT devices the computable operating systems were designed. All these type of Operating systems NANO-RK is prominent operating system designed for IoT devices[6]. The features of NANO-RK runs minimal 2 kb of RAM, supports C, C++, Multithread support, Resource Reservation capability.

NanoRK takes advantage of priority-based pre-emptive scheduling to help honor the real-time factor of being deterministic thus ensuring task timeliness and synchronization. Due to the characteristic of limited battery power on the wireless node, Nano-RK provides CPU, network, and sensor efficiency through the use of virtual energy reservations, labeling this system as a resource kernel. These energy reservations can enforce energy and communication budgets to minimize the negative impact on the node's operational lifetime from unintentional errors or malicious behavior by other nodes within the network. It supports packet forwarding, routing and other network scheduling protocols with the help of a light-weight wireless networking stack. Compared with other current sensor operating systems, Nano-RK provides rich functionality and timeliness scheduling with a small-footprint for its embedded resource kernel (RK).[6]

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II- AN OVERVIEW OF REAL-TIME OPERATING SYSTEM (RTOS)

The real-time applications are run by real-time operating systems. These operating systems knows as RTOS and guarantees executing the real-time applications in a consistent timing to meet high degree of control over tasks and allow to meet dead lines. In hard-real times operating system completion of a task beyond its deadline it is considered as useless. The soft real time systems tolerate latency and use up unused slack cycles of other processes.

The basic difference of using a GPOS or an RTOS lies in the nature of the system – i.e whether the system is **"time critical"** or not! A system can be of a single purpose or multiple purpose. Example of a "time critical system" is – Automated Teller Machines (ATM). Here an ATM card user is supposed to get his money from the teller machine within 4 or 5 seconds from the moment he press the confirmation button. The card user will not wait 5 minutes at the ATM after he pressed the confirm button. So an ATM is a time critical system. Where as a personal computer (PC) is not a time critical system. The purpose of a PC is multiple. A user can run many applications at the same time. After pressing the SAVE button of a finished document, there is no particular time limit that the doc should be saved within 5 seconds. It may take several minutes (in some cases) depending upon the number of tasks and processes running in parallel.

Nano-RK, a embedded real-time operating system with networking support. Nano-RK supports many sensor networking applications such as surveillance and environmental monitoring are time-sensitive. To support such type of applications, the implementation of Nano-RK, having best features like reservation-based real-time operating system (RTOS) with multi-hop networking support for the wireless sensor networks[7].

Since sensor nodes are resource-constrained and energy constrained, the Nano-Rk provide functionality enforce limits on the resource usage of individual applications and on the energy budget used by individual applications. Nano-Rk having best capability of CPU reservations and Network Bandwidth reservations wherein dedicated access of individual application to system resources is guaranteed.. The CPU, network and sensor reservation values of tasks can be iteratively modified by the system designer until the battery lifetime requirements of the node are satisfied.

III- LITERATURE SURVEY

Infrastructural software support for sensor networks was introduced by Hill et al. in [8]. They proposed TinyOS, a low-footprint component-based operating system that supports modularity and concurrency using an event-driven approach. TinyOS 1.0 supports an event-driven model wherein interrupts can register events, which can then be acted upon by other nonblocking functions. We believe that there eare several drawbacks to this approach. The TinyOS design paradigm is a significant departure from the traditional programming paradigm involving threads, making it less intuitive for application developers.

In contrast, there must be a support a traditional multitasking paradigm retaining task abstractions and multitasking. Unlike TinyOS, where tasks cannot be interrupted, we support priority-based pre-emption. Nano-RK provides timeliness guarantees for tasks with real-time requirements. We provide task management, task synchronization and high-level networking primitives for the developers use. While our footprint size and RAM requirements are larger than that of TinyOS, the requirements are consistent with current embedded microcontrollers. A sensor network microcontroller may typically have32-64KB of ROM and 4-8KB of RAM. Therefore, Nano- RK is optimized primarily for RAM and secondarily for ROM.SOS[9] is architecturally similar to TinyOS with the additional capability for loading dynamic runtime modules. In contrast to SOS, we propose a static, multitasking paradigm with timeliness and resource reservation support.

The Mantis OS [10] is the most closely related work to ours in the existing literature. In comparison to Mantis, this paper provide explicit support for periodic task scheduling that naturally captures the duty cycles of multiple sensor tasks. This paper support real-time task sets that have be in deadlines associated with their data delivery. This paper use the mechanisms of CPU and network reservations to enforce limits on the resource usage of individual tasks. With respect to networking we provide a rich API set for socket-like abstractions, and a generic system support for network scheduling and routing. Nano-RK supports power management techniques and provides several power-aware APIs for system use.

While low-footprint operating systems such as µC/OS, OSEK and Emeralds[11] supportreal-time scheduling, they do not have support for wireless networking. Our networking stack is significantly smaller in terms of foot print as compared to existing implementation of wireless protocols like Zigbee(around 25 KB ROM and 1.5 KB RAM) and Bluetooth (around 50KB ROM).We also provide high-level socket-type abstractions, and hooks for users to develop custom MAC protocols.

This research paper provides system infrastructure can be used to complement distributed sensor applications such as an energy-efficient surveillance system ([12, 13]). Study the literature on real-time networking/ resource allocation protocols [14,15], energy-efficient routing/ scheduling schemes [16, 17] , data aggregation schemes [18], energy efficient topology control [20] and localization schemes [21, 22]. Nano-RK can be used as a software platform for building higher-layer middleware abstractions like [23]. The study of energy reservation mechanism can also be used to prevent the type of energy DoS attacks described in [24].

Finally, our work complements [25] in extending the Resource Kernel (RK) paradigm to energy-limited resource constrained environments like sensor networks (and hence the name"Nano-RK").

IV - FEATURE OF NANO-RK

A.The Design of A Resource Kernel

Nano-RK was developed by Carnegie Mellon University. The design paradigm is to meet multi-hop networking for wireless sensor network.

The Real Time Operating Systems like Tiny Os, MantisOs having dis-advantages like timeliness guarantee for the process of task completion with a real time environments. Low level capability of high level networking premitivies and task management support.

Due to the characteristic of limited battery power on the wireless node, Nano-RK provides CPU, network, and sensor efficiency through the use of virtual energy reservations, labeling this system as a resource kernel. These energy reservations can enforce energy and communication budgets to minimize negative impact on the node's operational lifetime from unintentional errors or malicious behavior by other nodes within the network. It supports packet forwarding, routing and other network scheduling protocols with the help of a light-weight wireless networking stack. Compared with other current sensor operating systems, Nano-RK has optimized its microcontroller for current trends in hardware configuration of larger ROM (32-64KB) and smaller RAM (4-8KB)[3]. Thus, it provides rich functionality and timeliness scheduling with a small-footprint for its embedded resource kernel (RK).

B.The features of Nano-RK

Memory management

Nano-RK uses a static design-time approach for energy usage control. Dynamic task creation is disallowed by Nano-RK requiring application developers to set both task and reservation quotas/priorities in a static testbed design. This design allows the developers to create an energy budget for each task in order to maintain application requirements as well as energy efficiency throughout the system's lifetime. Using a static configuration approach, all of the runtime configurations as well as the power requirements are predefined and verified by the designer before the system is deployed and executed in the real world. This approach also helps to guarantee the stability and small-footprint characteristics when compared with traditional RTOSs.

Fault management system

To manage fault management system, in Nano-Rk posses Watchdog mechanism that triggers a system reset action if the system hangs on for a critical faults. The Watchdog is a software timer, that brings the system back from nonrepective state into normal operation by waiting until the timer goes off and reboot the device. In Nano-Rk the watchdog timer is connected directly to the processor's reset signal reboot on error. Default it is put into enabled state when the system boot and reset each time the scheduler executes.

Power management

Deep Sleep Mode is one of the feature of Nano-RK. It is the best method energy saving. For saving energy efficiency, if there are no eligible tasks to run, the system can be powered down and given the option to enter deep sleep mode. When the system is in deep sleep mode, only the deep sleep timer can wake the system up with a predefined latency period. After waking up from the deep sleep mode, the next context swap time is set to guarantee the CPU wakes up in time. If a sensor node does not wish to perform deep sleep, it also is presented with the choice to go into a low energy consumption state while still managing its peripherals.

Scheduling tasks-

The core of Nano-RK is a static preemptive real-time scheduler which is priority-based and energy efficient. For priority-based preemptive scheduling, the scheduler always selects the highest priority task from the ready queue. To save energy, tasks do not poll for a resource but rather tasks will be blocked on certain events and can be unlocked when the events occur. When there is no task in the ready queue, the system can be powered down to save energy. When the system is working, one and only one task (current task), signified by the nrk cur task tcb, is running for a predefined period. So the most important job of the scheduler is to decide which task should be run next and for how long the next task should be run until the scheduler is triggered to run again.

Network management & Communication Protocol Support

For sensor networks the primary goal in network management is minimizing energy use and the main means for doing this is by reducing the amount of communication between nodes, because more energy is utilized for data transfer during the communication between nodes.

Nano-RK supports multi hop networking & provides a lightweight networking protocol stack that provides a communication abstraction similar to sockets. To handle memory more efficiently, transmit and receive buffers are managed by the application. OS copies the received data into the application buffers. Once the data is placed into the application buffer, the application is notified accordingly.

A Time Synchronized Link Protocol, RT-Link provides support for real-time applications through bounded endto-end delay across multiple hops using Scheduled slots, and collision free transmission [7]. It is implemented over a TDMA link layer protocol, where each node transmits the data in predefined time slots, allowing for energy savings. In case of new mobilenode, contention slot is assigned to it using which it makes a reservation request to a gateway. Its membership keeps on changing with time.

V-RELATED WORK

By using Nano -RK, the following real-time problem solving in Internet of things as follows.

A Resource Reservation
B. Deep Sleep Mode
C. Fault management
D. Routing

A. Resource Reservations

The best feature of NanoRK is Resource Reservations. This paradigm, as implemented in a Resource Kernel [21], is a practical paradigm for guaranteeing timeliness in real-time operating systems.

The NanoRK enforces guaranteed access to system resources and also the scheduling tasks for that reason the satisfaction of application timeliness requirements. The resource reservation paradigm is desirable for dynamic and as well as static setting. A sensor application task can specify its requirement of CPU cycles, network bandwidth and network buffers over fixed periods which will be enforced by the NanoRK kernel. The sensor nodes have some constraints that exactly a single task is associated with a reservation.

The important design aspects of Nano-RK supports CPU reservations, sender/receiver network bandwidth reservations and sensor/actuator reservations[6]. All of these reservations can be combined to enforce a virtual node-wide energy reservation[25].

Experimental scenario 1

In constrained nodes, the battery life saving is increase the life time of sensor nodes. To maximize the battery life time, the proper utilization of energy reservations and network bandwidth reservation is important. To pushes the sensor data to gateway, the sensor nodes topological organized to form a forwarding tree. The duty cycles of individual nodes are chosen for life time of sensor networks. The energy reservations are remains connected upto over its operational life time to manage is continuously energy in a distributed sensing system The experimental setup consisted of a sensor network that was arranged as shown in figure with a target lifetime of 2 years.

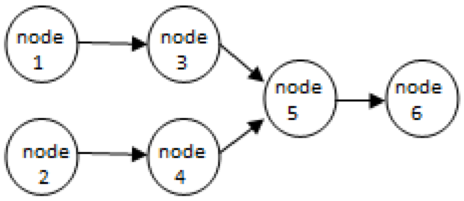
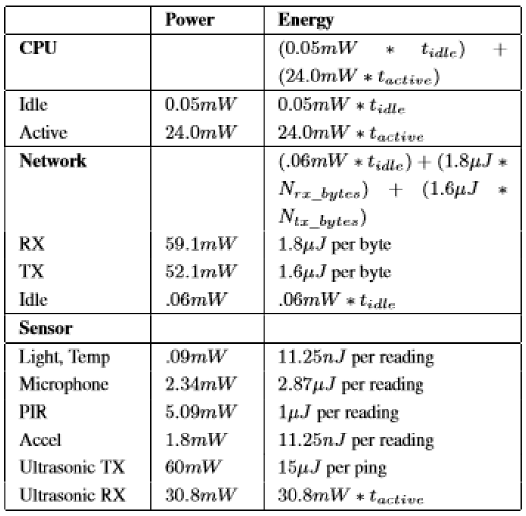


Fig1.
Energy reservation experiment

The sensor networks are topologically organized to form a forwarding tree that pushes sensor data to one or more gateway. The guarantee the lifetime requirements of sensor network depend upon the duty cycles of each node. The distributed systems concept, applications are configured in sensor nodes energy non-friendly status for that the transmitting of number packets to the gateway. In that manner energy will be consuming and the lifetime of sensor nodes will be shorten. In this paper, the sensor nodes in a network are arranged for getting target life time of atleast 2 years. Here the NANO-Rk is realtime operating system to handle the packets. If resource reservations not used, then operating system transford these packets up the tree. For that energy efficinet forwarding packets aggregated as single packet, then this aggregated packet forwarding upto the tree. Why because thethe payload data is range 2-4 bytes only. In this type of scenario the duty cycles of all nodes are equal in the network. In this table the node d was configured incorrectly for that reason, the d node send500 packets every 10 senconds rather than 1 packet per every 10 seconds.

Table 1: Energy statistics for current Enforcement from Energy Reservations Hardware setup



	Power	**Energy**
CPU		$(0.05mW * t_{idle}) + (24.0mW * t_{active})$
Idle	$0.05mW$	$0.05mW * t_{idle}$
Active	$24.0mW$	$24.0mW * t_{active}$
Network		$(.06mW * t_{idle}) + (1.8\mu J * N_{rx\_bytes}) + (1.6\mu J * N_{tx\_bytes})$
RX	$59.1mW$	$1.8\mu J$ per byte
TX	$52.1mW$	$1.6\mu J$ per byte
Idle	$.06mW$	$.06mW * t_{idle}$
Sensor		
Light, Temp	$.09mW$	$11.25nJ$ per reading
Microphone	$2.34mW$	$2.87\mu J$ per reading
PIR	$5.09mW$	$1\mu J$ per reading
Accel	$1.8mW$	$11.25nJ$ per reading
Ultrasonic TX	$60mW$	$15\mu J$ per ping
Ultrasonic RX	$30.8mW$	$30.8mW * t_{active}$

Table 2- Enforcement from Energy Reservations

Node	Reserve [TX pkt/10 sec. RX ptk/10 sec.	TX Rate [pkt.10 sec]	Total packets handled without reserve	Total packets handled with reserve
1	[1,2]	1	500	500
2	n/a	500	175000	1750 00
3	[1,2]	1	1150	1350
4	[1,2]	1	175000	1250
5	[1,2[	1	185600	2120

In table 1 shows the details of power characteristics of sensor node. In table 2 shows, counter values of each node as per characteristics to calculate mean power of every node with maximum mean power. The network lifetime was found to be 30 days with reserve reservations and 33 months without reserve reservations.

Experimental scenario 2

This research paper highlight the Nano-Rk to make reserve reservation to make increase of lifetime of nodes in a network. The nodes of lifetime of a node without reservations and the node with reservation is experimentally shows the details in table. The deployed node becomes faulty during its lifetime by broadcasting messages without a constraint. For this result, the listening nodes like node4, node5 forward unwanted packets from the node 2 gateway node i.e. node6.The Nano-Rk uses resource reservation protocol for increase the lifetime of a node using reservation of resources. Without reservation-based protocol the number of packets unwontedly transferring by nodes, these nodes shorten their lifetime from 3-5 years down to 3-4 days. With this concept, Nano-Rk shows managing energy efficiency by resource reservations strategy.

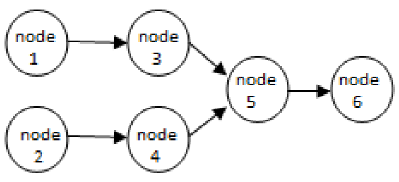


Fig2 – nodes in a network

node	Reserve [TX pkt/10 sec. RX ptk/10 sec.	TX Rate [pkt.10 sec]	Lifetime without reserve	Lifetime with reserve
1	[1,2]	1	5 years	5 years
2	**n/a**	**200**	**3 days**	**3 years**
3	[1,2]	1	5 years	5 years
4	**[1,2]**	**1**	**4 days**	**5 years**
5	[1,2[	1	4 days	4 years

Fig3. Without using energy reservation

2. Deep Sleep Mode

Deep sleep mode is the important feature of Nano-Rk to manage energy efficiency resources. The sensor nodes having the limited battery resources. The battery life is short period. The Nano-Rk using energy saving method by using deep sleep mode.

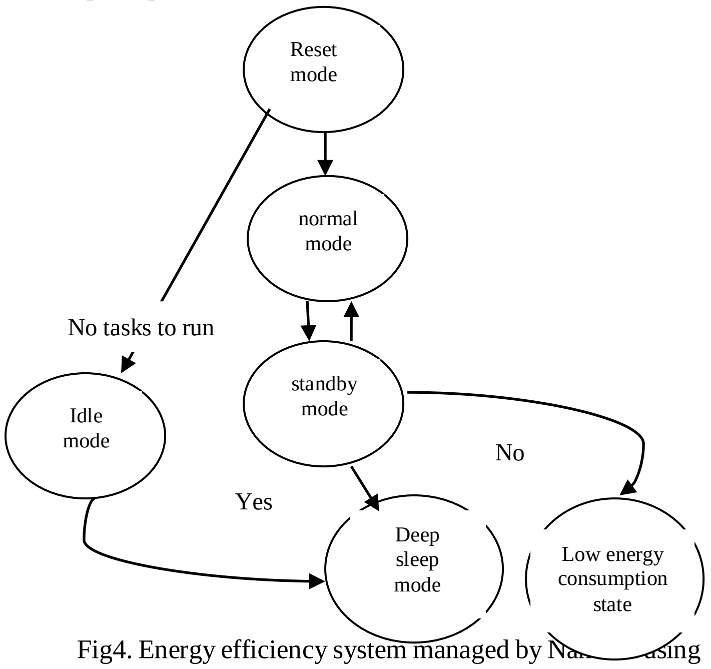


Fig4. Energy efficiency system managed by Nano-Rk using Deep sleep mode

In this scenario, If the sensor node, no tasks to run, then the status of the system will be powered down and entering into deep sleep mode. In this status, the deep sleep timer can wake the system up with a predefined latency period. The swap time is set to guarantee the CPU wakes up in time after waking up from deep sleep mode. It is a choice to sensor node, to go into a low energy consumption state when the sensor node does not wish to in deep sleep status. This way, the Nano-Rk perform energy management by deep sleep mode of any sensor node in a network[27].

3.Fault management

Watchdog is a software timer that triggers a system reset action if the system hangs on crucial faults for an extended period of time. The watchdog mechanism can bring the system back from the nonresponsive state into normal operation by waiting until the timer goes off and subsequently rebooting the device. In Nano-RK, the watchdog timer is tied directly to the processor's reset signal REBOOT ON ERROR. By default, it is enabled when the system boots and reset each time the scheduler executes. If the system fails to respond within the predefined time period, the system will reboot and run the initialization instruction sequence to hopefully proper control.

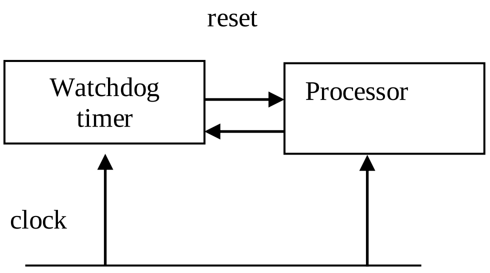
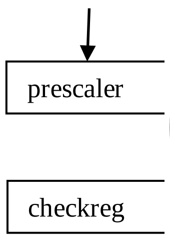
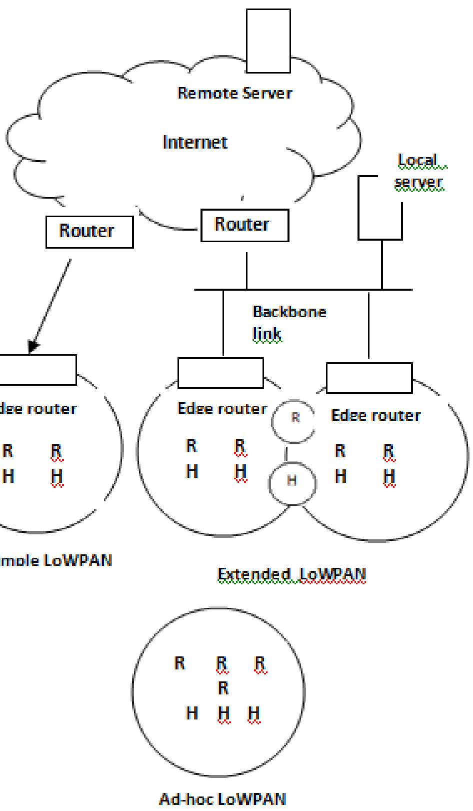


Fig5. Watch dog timer in ATM

A practical scenario by Nano-Rk operating system to manage constrained devices properly. It is an experimental scenario by Nano-Rk os using Watch dog timer for ATM ATM timeout using a watchdog timer. In this scenario, a watchdog timer is used to implement a timer out for an automatic teller machine (ATM). ATM session introduces a user inserting a bank card, the user typing in a personal identification number (PIN), and then answering questions about whether to balance enquiry or withdraw money, while selecting this option by the user, immediately the user chooses the required amount to withdraw from ATM. We want to design the ATM such that it will terminate the session if at any time the user does not press any button for a minute. In this case, the ATM will eject the bank card and terminate the session.

Working procedure–
As oscillator signal, OSC is connected to prescaler that divides the oscillator frequency by 12 (OSC/12) to generate a signal clk. The signal clk is connected to an 11-bit up counter scalereg. When scalereg overflows, it rolls over to "o", and its overflow output causes the 16-bit up counter timer reg to increment. If timing overflows, it triggers the system reset or an interrupt. To reset the watchdog timer, checkreg must be enabled. Then a value can be loaded into timereg.When a value is loaded into timereg, the checkreg register is automatically reset.
If the checkreg register is not enabled. a value can not be loaded into timereg. This is to prevent erroneous software from unintentionally resetting the watchdog timer.





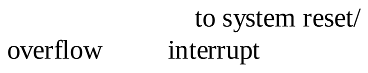


Fig6: ATM timeout using a watchdog time structure

Scenario 2 Example
Battery life mange for mobile phone display screen using Nano-RK -

Applications of watch dog timer is also implement in mobile phones. An application in mobile phone is that display is off in case no GUI interaction takes place within a watched time interval. This will save good amount of battery power.

4. Packet Routing

Nano-RK is a fully preemptive reservation-based real-time operating system (RTOS) with multi-hop networking support for use in wireless sensor networks. Nano-RK currently runs on the FireFly Sensor Networking Platform as well as the MicaZ motes.

The FireFly 3 is an ATmega128rfa1 powered wireless sensor device with the following specifications such as 16MHz with 32KHz low-power clock, Integrated 802.15.4 compatible 2.4GHz radio,16KB RAM, 128KB FLASH, and 4KB EEPROM and 2 UARTS, I2C, SPI, GPIO, ADC.

It includes a light-weight embedded resource kernel (RK) with rich functionality and timing support using less than 2KB of RAM and 18KB of ROM. Nano-RK supports fixed-priority preemptive multitasking for ensuring that task deadlines are met, along with support for CPU, network, as well as, sensor and actuator reservations. The important features of Nano-Rk is the tasks can specify their resource demands and the operating system provides timely, guaranteed and controlled access to CPU cycles and network packets. Together these resources form virtual energy reservations that allows the OS to enforce system and task level energy budgets.

This paper connects the full IPv6 stack to the nano-rk operating system by implementing 6LoWPAN. It guarantee to which enables the use of IPv6 over wireless embedded systems. The benefits of using 6LoWPAN include Open, long-lived, reliable standards,Easy learning curve, Transparent Internet integration, Network maintainability, Global scalability, End-to-end data flows

Architecture of 6lowpan –
Overall, there are two main parts in implementing the network and the Edge Router.

Fig7. Architecture of 6LoWPAN

Node architecture

The routing is one of the primary aspects of wireless networks system. As per specification of 6LoWPAN to implement the Routing Protocol (RPL) from the Routing Over Low Power and Lossy Networks (ROLL) work group.

Routing protocols perform well for adhoc networks. The network is ad hoc because it does not rely on a pre-existing infrastructure. The routing protocol is optimized for up/down stream routing to and from a root node. This type of RPL paradigm is very closely aligned to networks connected to the super netting i.e. Internet.

The routing packets of Routing Protocol (RPL) are sent via Internet Control Message Protocol (ICMPV6) packets. The packet is not belonging a particular nodes and this node receives a packet then automatically communicate Routing Protocol (RPL) for where to transfer this received packet. Here the implementation is to transfer of this packet route over IP Address instead of forwarding with Media Access Control (MAC) address. This is recommendation of 6LoWPAN specifications.

Edge router architecture
The main process of edge router is accepting any incoming IPV6 packets and convert it to 6LoWPAN packets and take any outgoing 6LoWPAN packets and converts it to IPV6 packets. This is a strong recommendation of edge router and integration with ipv6 and necessary to implementation a 6LoWPAN network driver.

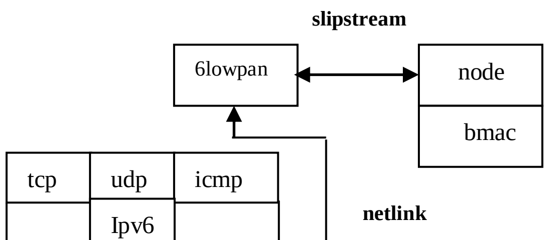


Fig 8: Edge router architecture

The edge router logic running in user space for that reason did not crash the kernel whenever a bug occurred. Here the debugging tools gbd used for debugging in user space. The user-space process which communicates with the 6LoWPAN network driver via a netlink sockets. The heavy router responsible is user-space process. The router recommends features like compression/decompression, fragmentation/defragmentation, routing tables, acting as the root RPL node and bootstrapping.

The edge router communicates with nodes by setting up a slipstream communication link with a spare node from user-space mod. All packets which the edge router wants to send to the network are just sent to this spare node over slipstream. The spare node then sends the packets over Berkeley ***MAC*** (bmac) on behalf of the edge router. Any packets received by the node via bmac are forwarded to the user-space process. In this way edge router is encapsulated in the user-space process

CONCLUSION

In this paper, we described Nano-RK, a reservation-based energy-aware real-time operating system with wireless networking support for resource-constrained sensor network environments. We support a classically structured multitasking OS with API support for task management, synchronization, IPC and high-level networking abstractions, with these functions specifically tailored to the constrained sensor network environments. We enforce limits on CPU, bandwidth and sensor usage of individual tasks by using a reservation-based approach to enforce bounds on timeliness, QoS and node lifetime. We adopt a static design-time approach as compared to a dynamic run-time approach for creating an embedded sensor taskset. OurOS design uses several optimizations for memory and energy-efficiency reasons while retaining a richest of capabilities. Nano-RK will be made available for public use in the near future.

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