Power Aware Methodologies for Wireless Microsensors

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Abstract

Microsensors are used in monitoring functions in several hazardous and non reachable places. At such places human intervention is impossible so battery replacement is impossible and hence nodes do not have access to unlimited energy. Thus, designing fault-tolerant wireless microsensor networks with long system lifetimes can be challenging. In order to prolong system lifetimes, energy-efficient algorithms and protocols should be used. So, in this paper we study the techniques which are used for low power consumption as these are necessary for system to achieve both flexibility and energy efficiency and maximize the lifetime. Energy is minimized through the use of highly dedicated computational fabrics and through careful conditioning of logic based on signal statistics and by using techniques like DVS, CIMS, and multihop communication.

Keywords: *Low Power Consumption, Wireless Sensor Network, DVS, Energy Saving, Energy Harvesting*

1. Introduction

Microsensors are used for variety of operations including environmental data collection, battlefield monitoring, biomedical etc. Sensor nodes are deployed for such purposes by letting them fall randomly from air planes. These sensors are very small, cost effective and energy efficient devices with vey low initial power. The sensor nodes sense the data, process it and then communicate it to central base station. Despite the increasing capabilities of sensor nodes, there are some limitations; they have a limited amount of memory, processing power and most importantly energy. Sensor nodes are typically battery powered and battery replacement is infrequent or even impossible in many sensing applications. The need to minimize energy consumption while maintaining user constraints makes the design of wireless microsensor networks challenging. While techniques to minimize the energy consumption of portable, multimedia devices have been studied extensively these techniques may not be applicable to wireless microsensors. For example, while conventional hand-held devices only need to last hours or days, microsensor nodes need to last several years. Therefore, different energy-efficient techniques will need to be applied.

In this paper, we will study several methodologies for lowering the power consumption. The data is mostly transmitted from sensors node to base station and very less in opposite direction. By using these facts methods like DVS and reducing the stand by leakage at low duty cycles can be used. The CMOS Integrated Microsystems (CIMS) [4] process may provide high performance, as the advancement in CMOS can be integrated with sensors by providing system flexibility to update the technology at later stage of the design. As sensors have initial very low energy, so the energy can be harnessed from the environment i.e., using ambient energy to power electronic circuits. Latency and performance requirement are met for low power methods by using energy aware approaches by employing energy aware circuits. And at last, a lot of energy is consumed in transmission of data from the sensor nodes, so communications protocols like multihop routing and concept of power aware middleware is established. We have laid so much stress on lowering the energy consumption, because it enhances the lifetime of the node, moreover reducing the power consumption results in cost effective, light weight and more compact design of sensors nodes. This paper addresses some of the key design consideration for future microsensor systems including the network protocols required for collaborative sensing and information distribution, system partitioning considering computation and communication costs, low energy electronics, power system design and energy harvesting techniques.

2. Architecture for a Power Aware Distributed Microsensor Node

An initial design of a sensor node that illustrates power-aware design methodologies is shown in Fig 1. This system, the first prototype of our µAMPS (micro-Adaptive Multi-domain Power-aware Sensors) effort is designed with commercial off-the-shelf components for rapid prototyping and modularity [1].

2.1 Power Supply:

Power for the sensor node is supplied by a single 3.6V DC source, which can be provided by a single lithium-ion cell or three NiCD or NiMH cells. Regulators generate 5V, 3.3V and adjustable 0.9-1.5V supplies from the battery. The 5V supply powers the analog sensor circuitry and A/D converter. The 3.3V supply powers all digital components on the sensor node with the exception of the processor core. The core is powered by a digitally adjustable switching regulator that can provide 0.9V to 1.6V in twenty discrete increments. The digitally adjustable voltage allows the SA-1100 to control its own core voltage, enabling dynamic voltage scaling techniques.

2.2 Sensors:

The node includes seismic and acoustic sensors. The seismic sensor is a MEMS accelerometer capable of resolving 2mg. The acoustic sensor is an electret microphone with low-noise bias and amplification. The analog signals from these sensors are conditioned with 8^{th}order analog filters and are sampled by a 12-bit A/D. The high-order filters eliminate the need for oversampling and additional digital filtering in the SA-1100. All components are carefully chosen for low power dissipation; a sensor, filter, and A/D typically require only 5mA at 5 Volts.

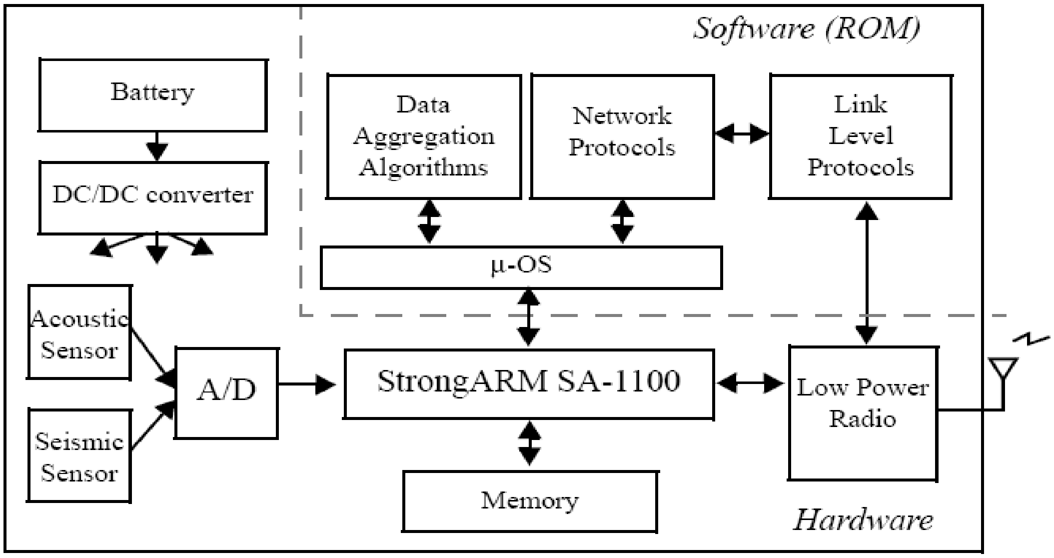

Figure 1: A sensor node hardware & software framework

2.3 Microprocessor and Operating System:

A Strong ARM SA-1100 microprocessor is selected for its low power consumption, sufficient performance for signal processing algorithms, and static CMOS design. The memory map mimics the SA- 1100 “Brutus” evaluation platform and thus supports up to 16MB of RAM and 512KB of ROM. The lightweight, multithreaded “µOS” running on the SA-1100 is an adaptation of the eCOS microkernel that has been customized to support the power-aware methodologies. The OS, data aggregation algorithms, and networking firmware are embedded into ROM.

2.4 Radio:

The radio module interfaces directly to the SA-1100. The radio is based on a commercial single-chip transceiver optimized for ISM 2.45GHz wireless systems. The PLL, transmitter chain, and receiver chain are capable of being shut-off under software or hardware control for energy savings. To transmit data, an external voltage-controlled oscillator (VCO) is directly modulated, providing simplicity at the circuit level and reduced power consumption at the expense of limits on the amount of data that can be transmitted continuously. The radio module is capable of transmitting up to 1Mbps at a range of up to 15 meters.

3. Power aware methodologies

In this section, we present energy-scalable design methodologies geared specifically toward our microsensor application [1]. At the hardware level, we note the unusual energy consumption characteristics affected by the low duty cycle operation of a sensor node, and adapt to varying active workload conditions with dynamic voltage scaling. At the software level, energy-agile algorithms for sensor networks such as adaptive beam forming provide energy-quality tradeoffs that are accessible to the user. Power-aware system design encompasses the entire system hierarchy, coupling software that understands the energy-quality tradeoff with hardware that scales its own energy consumption accordingly.

3.1 Low Duty Cycle Issues

The energy consumption characteristics of the components in a microsensor node provide a context for the power-aware software to make energy-quality tradeoffs. Energy consumption in a static CMOS-based processor can be classified into switching and leakage components. The switching energy is expressed as:

$$Eswitch=C_{tot} * V_{dd} * V_{dd} \qquad (1)$$

Where C_{tot} is the total capacitance switched by the computation and V_{dd} is the supply voltage. Energy lost due to leakage currents is modeled with an exponential relation to the supply voltage:

$$Eleak = (V_{dd} *t)Ioexp(V_{dd}/nV_t) \qquad (2)$$

While switching energy is usually the more dominant of the two components, the low duty cycle operation of a sensor node can induce precisely the opposite behavior. For sufficiently low duty cycles or high supply voltages, leakage energy can exceed switching energy. For example, when the duty cycle of the Strong ARM SA-1100 is 10%, the leakage energy is more than 50% of the total energy consumed. Techniques such as dynamic voltage scaling and the progressive shutdown of idle components in the sensor node mitigate the energy consumption penalties of low duty cycle processor operation [2]. Low duty cycle characteristics are also observable in the radio. Ideally, the energy consumed per bit would be independent of packet length. At lower data rates, however, the start-up overhead of the radio's electronics begins to dominate the radio's energy consumption. Due to its slow feedback loop, a typical PLL-based frequency synthesizer has a settling time on the order of milliseconds, which may be much higher than the transmission time for short packets. Particular effort is required to reduce transient response time in low power frequency synthesizers for low data rate sensor systems [3].

3.2 Dynamic Voltage Scaling

Dynamic voltage scaling (DVS) exploits variability in processor workload and latency constraints and realizes this energy-quality tradeoff at the circuit level. As discussed above, the switching energy of any particular computation is $Eswitch= C_{tot} * V_{dd} * V_{dd}$, a quantity that is independent of time. Reducing V_{dd} offers a quadratic savings in switching energy at the expense of additional propagation delay through static logic. Hence, if the workload on the processor is light, or the latency tolerable by the computation is high, we can reduce V_{dd} and the processor clock frequency together to trade off latency for energy savings [10]. Both switching and leakage energy are reduced by DVS; as (2) indicates, leakage energy varies more than exponentially with V_{dd}, the measured energy consumption of a SA-1100 processor running at full utilization. As discussed above, a reduction in clock frequency allows the processor to run at lower voltage. The quadratic dependence of switching energy on supply voltage is evident, and for a fixed voltage, the leakage energy per operation increases as the operations occur over a longer clock period. The OS running on the SA-1100 selects one of the above eleven frequency-voltage pairs in response to the current and predicted workload [1]. A five-bit value corresponding to the desired voltage is sent to the regulator controller, and logic external to the SA-1100 protects the core from a voltage that exceeds its maximum rating. The regulator controller typically drives the new voltage on the buck regulator in under 100µs. Fig 2 illustrates the regulation scheme for our sensor node for DVS.

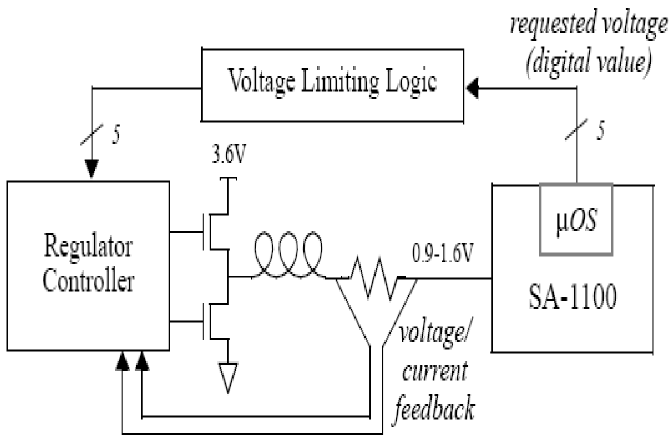

Figure 2: Regulation scheme for DVS

4. Low power wireless microsensor

A distributed, low power, wireless, integrated microsensor (LWIM) [4] technology can have set of unique requirements exist for distributed wireless microsensor networks. The individual low cost sensor nodes must be

- Reconfigurable by their base station,
- Autonomous to permit local control of operation and power management,
- Self-monitoring reliability,
- Power efficient for long term operation, and
- Must incorporate diverse sensor capability with highly capable, low power microelectronics.

Intelligent, wireless microsensor node technology, based on commercial, low cost CMOS fabrication and bulk micro- machining, has demonstrated capability for multiple sensors, electronic interfaces, control, and communication on a single device. LWIM nodes are fabricated by the new CMOS Integrated Microsystems (CIMS) process. CIMS provides high sensitivity devices for vibration, acoustic signals, infrared radiation and other diverse signal sources. The central challenges for low cost, manufacturable LWIM devices are the requirements for microcropower operation and the complete integration of a CMOS RF transceiver.

4.1 Low Power Wireless Microsensor Networks

Sensor network consist of a single base station and a no. of sensor nodes. In this network, most information flow from nodes to base station while very less information in form of commands flow in opposite direction. Network architecture and communication protocols must exploit this asymmetry of distributed sensor communication. Typical applications may be optimally serviced by sensor networks having local signal processing by sensor nodes. Thus, individual nodes may propagate measurements of battlefield environment, machine condition, or patient condition, periodically to the base station at low duty cycle. In particular, only upon an alarm condition will continuous data transmission be required. This method permits a base station to service a much larger network than would be possible for simple continuous communication with sensor node. In addition, low duty cycle operation, combined with proper power management, permits low power operation.

Periodic updates of the network base station, by distributed network sensor nodes, permits detection of changes in environmental or system operation. For example, individual sensor nodes may provide continuous measurement of a vibration spectrum, while only transmitting the observation of a change in this spectrum. By exploiting the low duty cycle requirements for sensor communication, large efficiencies may be obtained in sensor node and base station operation.Completely independent LWIM nodes must operate at micro-ampere current levels and low voltage. This allows long operating life from compact battery systems. Alternatively, for some condition based maintenance applications, with nodes mounted directly on a motor or drive train shaft, LWIM nodes may receive power by continuous or periodic reception of RF energy from a nearby power source via an inductive coupling. Typical low duty cycle, low data rate (10kbps) and short range (10-30m) communication permit 30pA average current for an LWIM node operating at 3V. A conventional, (2.5cm diameter, 0.7cm thickness) Li coin cell provides this current level for greater than three years of unattended operating life.

4.2 Low Power Wireless Microsensors: CMOS Microsensor Integration

The low power electronics for wireless microsensors exploits a new CMOS microsensor integration technology. The rapid reductions in the fabrication cost of CMOS digital circuit technology, along with improvements in performance, provide motivation for the development of CMOS compatible microsensor structures and measurement circuits.

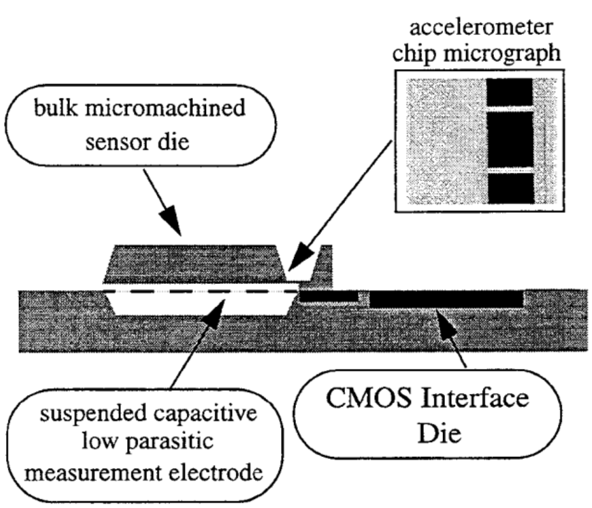

Figure 3: The Accelerometer

CMOS technology now conveniently provides the embedded control and micropower digital systems needed for intelligent microsensor nodes. CIMS [4] combines commercial CMOS (post-processed after foundry-fabrication by XeF_2 micromachining) with high performance bulk micro machined sensor and actuator structures (Fig.3) by flip chip bonding. The CIMS process employs an Interface Die that supports a sensor element, the CMOS interface die is fabricated by commercial foundries and may be post-processed after fabrication. The interface die may support measurement, control, and communication systems. The CIMS process offers several advances over previous techniques. First, by separating the CMOS and bulk micro-machining processes, conventional low cost CMOS technology may be directly applied. This offers system development flexibility to update the circuit technology rapidly to exploit the most optimum processes that become available. In addition, the separation of CMOS and sensor element fabrication permits the introduction of novel materials, eg. pyroelectric systems without disturbing critical CMOS processing. As an example, a CIMS accelerometer structure is shown in Fig 3.

5. Low duty cycle radio communication

Microsensors long idle periods and low data rates imply node-to-node communication with a low duty cycle and brief transmissions. The communication subsystem for wireless microsensors must therefore be optimized for these conditions. For short range transmission at GHz carrier frequencies, the power consumption of communication is dominated by the radio components (frequency synthesizer, mixers, etc.) rather than the actual transmit power radiated into the air. To conserve power, it is therefore essential that radio electronics be turned off during idle periods. Unfortunately, GHz-band frequency synthesizers require significant time and energy overhead to transition from the sleep state to the active state. For short packet sizes, the transient energy consumed during start-up can be significantly higher than the energy required by the electronics during the actual transmission.

5.1 Fast Start-up Low Power Transmitter

The start-up time of the transmitter is dominated by the frequency synthesizer due to the time required to stabilize its PLL. A popular approach to reduce the settling time is the use of a variable loop bandwidth [5]. The PLL is started with a wide loop bandwidth and is transitioned to a narrower loop bandwidth as the loop approaches lock.

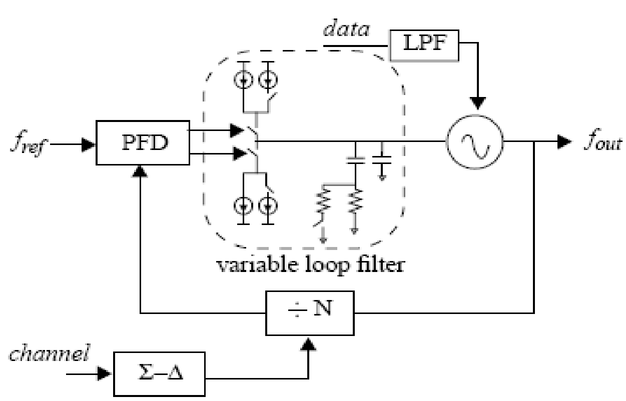

Figure 4: low power, fast startup transmitter

As this method requires simple overhead circuitry, it is attractive for low power PLL applications. The on-time of the transmitter must be reduced to lower the energy utilized per bit. One promising architecture for continuous phase-modulated signals is an indirect modulation method that uses sigma-delta in a fractional-N synthesizer. This architecture eliminates the need for mixers or DACs in the heterodyne scheme. Another compact architecture for continuous phase modulation is closed loop, direct VCO modulation. This architecture requires a low gain varactor on the VCO and supports simple BFSK modulation. Variable loop bandwidth reduces the start-up time by a factor of four.

5.2 Idle-mode Leakage Control

Microsensors typically spend most of their time in a standby mode, waiting for significant events to occur. Hence, powered components dissipate leakage energy over long periods of time. One approach to reducing idle mode energy dissipation is simply to shut off all unused electronics during idle mode. However, any energy savings from shutdown can be negated by the potentially large latencies and energy overheads required to power up the node from its off state. Idle mode energy is therefore best addressed at its source, the leakage currents flowing through idle circuits. Multiple-Threshold CMOS (MTCMOS), for instance, reduces idle mode leakage by employing high-V_{th} transistors to gate the power supplies to the logic blocks which are designed with low- V_{th} transistors. Designing sequential MTCMOS circuits is challenging since state is lost during sleep mode while the power supplies are floating. MTCMOS designs are prone to "sneak" (unexpected) leakage paths [6] through low- V_{th} gates. Leakage feedback flip-flops utilize leakage to hold state while avoiding sneak leakage paths .This circuit achieves performance close to a traditional low- V_{th} flip-flop while retaining the low leakage of a high-V_{th} flip-flop. Future digital systems must exploit multiple and variable threshold devices for leakage control.

6. Energy harvesting

As the power dissipation of entire sensor systems is reduced to hundreds of microwatts, it becomes possible to use ambient energy sources to power electronic systems. Various schemes have been proposed to eliminate the need for batteries in a portable digital system by converting ambient energy in the environment into electrical form [5]. The harvested electrical energy can be stored and utilized by the node's electronic circuits. The most familiar sources of ambient energy include solar power. Other examples include other types of electromagnetic fields (used in RF powered ID tags, inductively powered smart cards, or noninvasive pacemaker battery recharging), thermal gradients, fluid flow, and mechanical vibration. Other proposals include powering electronic devices through harnessing energy produced by the human body or the action of gravitational fields. Table 1 lists potential power output for a wide variety of energy sources. Starner models the power available from directly converting the energy of footsteps by inserting a piezoelectric transducer in the heel of a shoe. A direct transduction technique like this has the potential to generate large amounts of power, on the order of 5W. The usable energy, of course, will be significantly lower. Photovoltaic cells are the most popular transducer for converting ambient energy. Advances in solar cell technology have pushed efficiency toward 20%. Assuming a typical incident power density for light of 100mW/cm^2, this yields 20mW for 1cm^2 array. Besides light, other types of electromagnetic fields have been proposed as energy sources. Magnetic fields coupled using an on-chip inductor have been shown to generate 1.5mW of power, enough to power circuitry for a telephone card[2] .

Table 1. Examples of Ambient Energy Source

Energy Source	**Transducer**	**Power**
Walking (Direct Conversion)	Piezoelectric	5 W

Solar	Photovoltaic Cell	20mW
Magnetic Field	Coil	1.5mW
Walking (Vibration)	Discrete Moving Coil	400mW
High Frequency Vibration	MEMS Moving Coil	100mW
RF Field	Antenna	5mW

Two examples of power generation using mechanical vibration are shown here. The first uses a macroscopic generator coupled to vibrations produced by human walking and leads to a power output of 400mW and another is a MEMS transducer approach which, when coupled to a much higher frequency vibration source, produces 100mW of power.

6.1 Vibration Based Power Generator

One particular approach to using ambient energy sources for power involves transduction of mechanical vibration to electrical energy [7]. A generator based on transducing mechanical vibrations has some distinct advantages: it can be enclosed and protected from the outside environment, it functions in a constant temperature field, and it can be activated by a person.

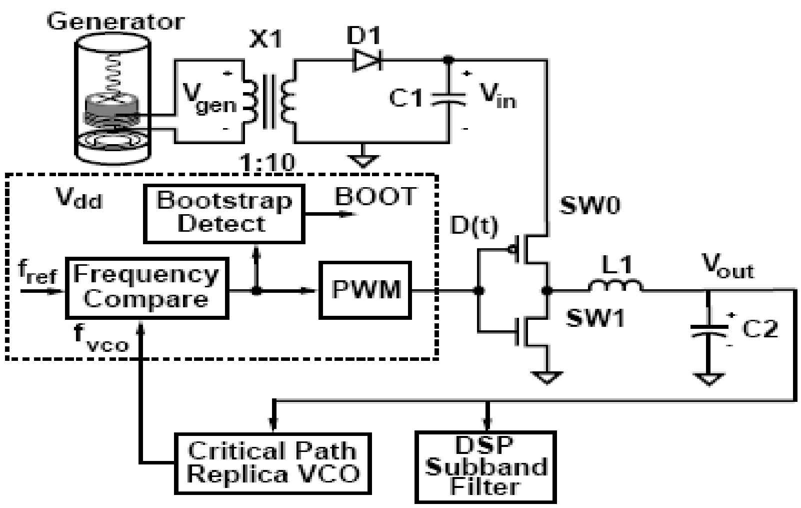

Figure 5(a): Vibration based self powered system

It is particularly suited for machine mounted sensors, where the vibration of the machinery provides the power, or body area sensors, where the movement of the human body generates vibrations that can be used as a power source. Fig 5(a) is a detailed block diagram of our self-powered system. A moving coil generator is used which consists of a mass attached to a spring, which is attached to a rigid housing. The generator and rectifier subsystem is shown at the top. Transformer X1 (with a 1:10 turns ratio) converts the output voltage of the generator V_{gen} to a higher voltage that can be rectified by the half-wave rectifier formed by diode D1 and capacitor C1. Note that with proper electromechanical design, the transformer can be eliminated. Voltage V_{in} is the time-varying input voltage to the regulator. The regulator consists of five main subsystems: a VCO, frequency comparator, pulse-width modulated (PWM) waveform generator, bootstrap detection circuit, and a Buck converter. To achieve the lowest possible power consumption, the converter down converts V_{in} to the lowest voltage at which the DSP can run and still produce correct results at the rate set by f_{ref}.

6.2 MEMS Generator

Advances in MEMS technology have enabled the construction of a self-powered system in which a MEMS device acts a power source for a digital load. The MEMS device [8] is a variable capacitor that converts mechanical vibration into electrical energy. The capacitor plates are charged and then moved apart by vibration, resulting in the conversion of mechanical energy into electrical energy. The device consists of three basic parts: a floating mass, a folded spring, and two sets of interdigitated combs. With appropriate regulation circuitry, this device delivers 10µW of power.

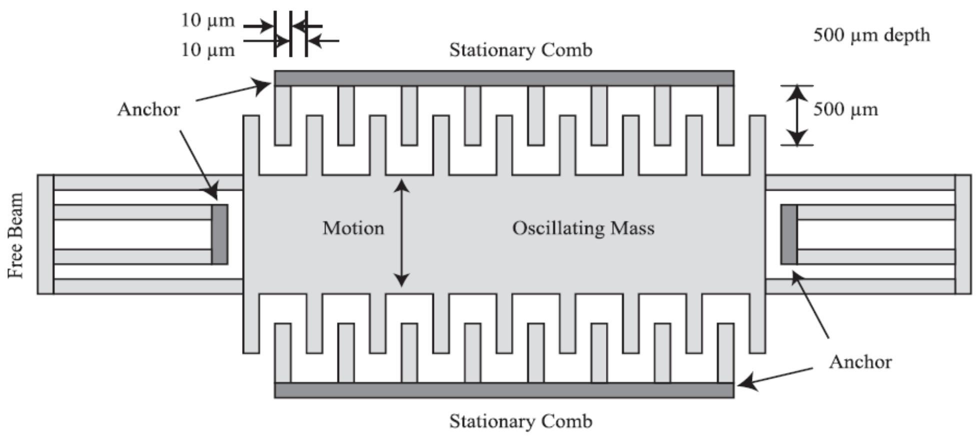

Figure 5(b): A plan view of MEMS generator

7. Energy aware computing

Energy scalability is an important trend that involves the system adapting to time-varying operating conditions. This is in contrast to current low-power approaches, which target the worst-case operating scenario. An energy-aware circuit monitors its available energy resources and dynamically adapts hardware parameters to meet latency and performance requirements. Hardware knobs that can be varied, range from circuit parameters such as bit-precision and supply voltage to system parameters such as the numbers of operations performed (e.g., filter length).

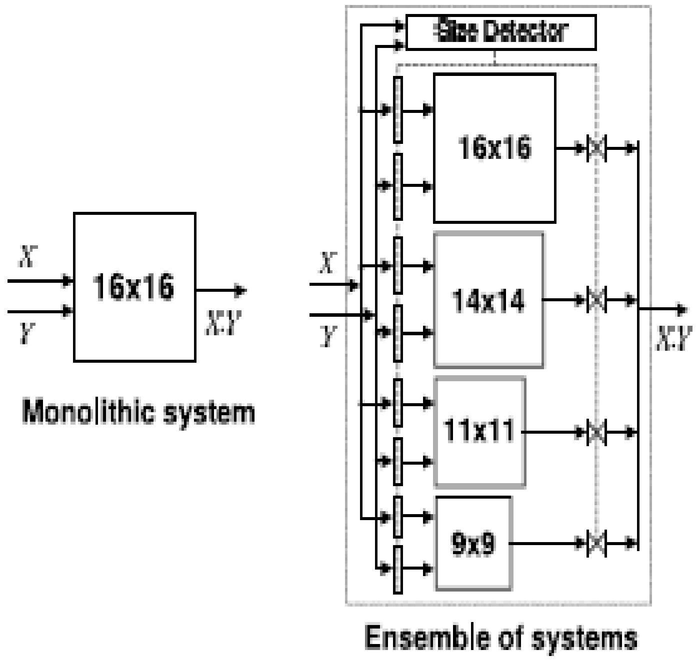

Figure 6: Comparison of Monolithic System and Ensemble of Systems

For instance, an arithmetic circuit such as a multiplier is subject to diversity in operand width. Multiplier circuits are typically designed for a fixed operand size, such as 32 bits per input; calculating an 8-bit multiplication on a 32-bit multiplier results in unnecessary switching of the high-order bits. This excess switching would not have occurred if the 8-bit multiplication had been performed on an 8-bit multiplier. As small operands can result in inefficient computation on larger multipliers, an architectural solution that improves energy awareness is the incorporation of additional, smaller multipliers of varying sizes, as shown in Fig6. Incoming multiplications are routed to the smallest multiplier that can compute the correct result, reducing the energy overhead of unused bits. An ensemble of point systems, each of which is energy-efficient for a small range of input widths, takes the place of a single system whose energy consumption does not scale as gracefully with input diversity. The size and composition of the ensemble is an optimization problem that accounts for the probabilistic distribution of the inputs and the routing energy overhead. For an operand bit width distribution typical of a speech application, the ensemble of Fig6 consumes 57% less energy than a monolithic multiplier [11].

8. Energy efficient communication

The energy consumption of node-to-node communication depends not only on the processing and radio hardware, but also the communication protocols that drive this hardware. It is essential to consider how protocols and software impact hardware energy consumption.

8.1 Energy of Multihop Communication

The energy of on-chip communication is approximately linear with distance, for the capacitances of one-dimensional interconnect scales linearly with distance. The energy required for inter-node communication, however scales with distance as *d*2 to *d*4. Since the path loss of radio transmission scales with distance in a greater than linear fashion, communication energy can be reduced by dividing a long transmission into several shorter ones [12]. Intermediate nodes between a data source and destination can serve as relays that receive and rebroadcast data. This concept, known as multihop communication, is analogous to the use of buffers over a long, on-chip interconnect. Let multihop communication to a base station across a distance *d* using *h* hops. Since the last hop is always received by an energy unconstrained base station, there are *h* transmitting and *h-1* receiving nodes. The introductions of relay nodes are clearly a balancing act between reduced transmission energy and increased receive energy. Hops that are too short lead to excessive receive energy. Hops that are too long lead to excessive path loss. In between these extremes is an optimum transmission distance called the characteristic distance d_{char} [9].

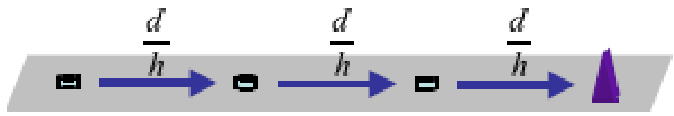

Figure 7(a): Multihop communication

The characteristic distance depends only on the energy consumption of the hardware and the path loss coefficient; d_{char} alone determines the optimal number of hops. For typical COTS-based sensor nodes, d_{char} is about 20m. The existence of a characteristic distance has two practical implications for microsensor networks. First, it is often impractical to ensure that all nodes are space exactly d_{char} apart. Nodes may dropped by air, or their deployment constrained by terrain or physical obstacles. The deployed nodes may be placed as, a line of nodes and a base station separated a distance of either *d* or 2*d*, with $d < d_{char} < 2d$, there are three possible multi-hop policies from the farthest node to the base station. Considering that none of the inter-node distances is exactly equal to d_{char}, what is the minimum-energy policy?

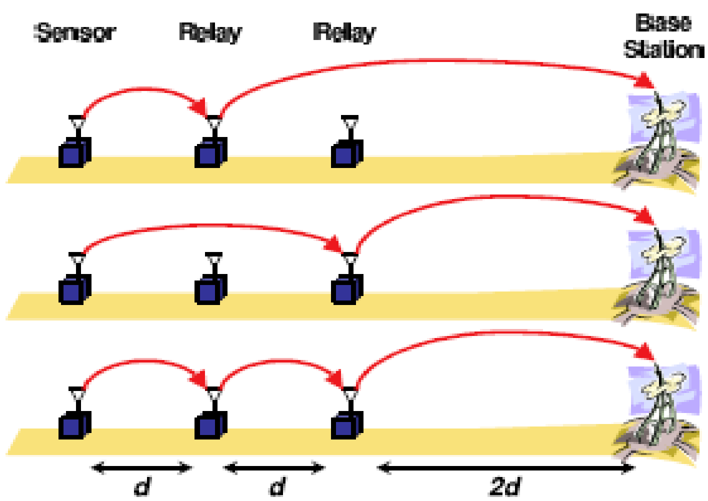

Figure 7(b): Three multihop policies when two nodes are b/w TX & RX

The optimal solution turns out to be a rotation of roles over time. The final numerical result depends heavily on the node energy models that quantify the trade-off between the path loss of transmission and the power dissipation of the radio electronics. For the energy models used, the optimal policy dictates that communication occur through each one of the one-hop routes 24.5% of the time, and through the two-hop route 51% of the time. This rotation of policies effectively dithers the transmission distance so that it approaches d_{char} when the actual nodes are not d_{char} apart. The second practical implication of a fairly large d_{char} is that there are large classes of applications for which the entire network diameter will be less than d_{char}. For these applications, the best communication policy is not to employ multihop at all; direct transmission from each node to the base station is the most energy-efficient communication scheme. For today's radio hardware, the typical d_{char} of 20m exceeds the size of many interior spaces. Hence, until advances in low-power receive technology lead to a reduction in d_{char}, most indoor microsensor networks will not save energy using a multihop routing protocol.

8.2 API (Application programmable interface)

Communication protocols, such as multihop routing [6], must take advantage of a microsensor node's energy scalability and awareness. The performance of communication can be quantified by three parameters: range, reliability, and latency. Range represents the distance to the recipient, reliability indicates the likelihood that the transmitted data is properly received, and latency measures the time required for the end-to-end communication. Applications can facilitate energy conservation by relaxing any of these parameters, allowing the communication hardware to trade performance for energy savings. Transmission range, for instance, can be reduced with a variable-power transmit amplifier. Reliability can be adjusted with variable strength forward error correction (FEC). Finally, DVS and clock frequency scaling can adjust the latency of digital computation (e.g., required for FEC) [10].

The remaining task is to set hardware "knobs" such as supply voltage, clock frequency and amplifier power such that the performance parameters requested by communication software are satisfied with minimal energy expenditure. Relating latency, reliability, and range to actual hardware energy consumption is a challenging task. Many parameters interact: range and reliability are closely linked, for instance, since a radio transmission becomes less reliably received as it travels farther from its sender.

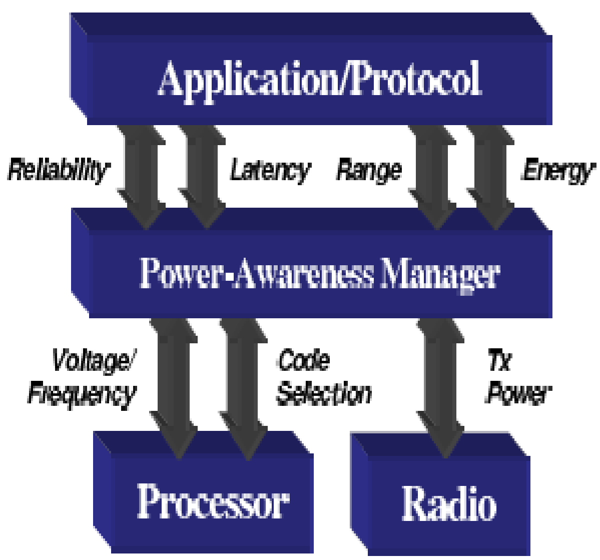

Fig8: Middleware convert communication performance requirement into optimal h/w settings

FEC strength impacts the energy consumption of both processor and radio: a stronger code not only consumes more digital processing resources, but also potentially increases the number of transmitted bits. Communication software requests performance in terms of meters and bit error rates, not supply voltages and power levels. Something must bridge the gap. The solution is a layer of power-aware "middleware" between the communication hardware and software. The middleware layer exposes an application programming interface (API) to communication software that allows the specification of constraints on latency, reliability, range, and total energy. The middleware translates these software constraints into the minimum-energy hardware policies that satisfy them. Given specifications of transmission distance and tolerable bit error rate from the application, the middleware selects the least-energy FEC scheme and transmission power level supported by the hardware.

9. Conclusion

A sensor networks comprises of application dependent sensor nodes with sensing, processing, storing and communication capabilities. This paper describes the challenges facing wireless microsensor design and presents general microsensor node architecture. The challenge for next generation nodes is to further reduce energy consumption by optimizing energy awareness over all levels of design. Energy dissipation, scalability, and latency must all be considered in designing network protocols for collaboration and information sharing, system partitioning, and low power electronics. Energy harvesting techniques that eliminate the need for battery source and provide “infinite” lifetime will become critical as the size of sensor systems grows. Energy scalability is also an important design consideration in these distributed sensors. Reducing startup time improves the energy efficiency of a transmitter for short packets and multihop routing reduces energy for long distance communication. The amount of resources available (e.g., battery life), the quality requirements (e.g., accuracy of sensing results), and the latency requirements can vary as a function of time. This has to be explicitly considered in the optimization of the system. For example, system-level power down can be exploited to scale quality or latency with respect to energy dissipation. At the circuit level, techniques such as dynamic voltage scaling allow the energy dissipation of a processor to be scaled with computation latency or Quality of Service. Lowering of the energy consumption is not the only goal but making system more power aware is our task. A power aware system priorities its need in terms of several parameters like increasing the life time or enhancing the quality on user’s request inherent to its property of adapting the changes according to the environment conditions. Lowering the power consumption makes the system more reliable and increases the lifetime. The techniques we studied here must be implemented in a mixed fashion so that benefits of combination of them can be used. By combining the software and hardware approaches the low power sensors devices can be used for achieving the maximum energy efficiency. A total-system approach is required for reliable, self-powered microsensor networks that deliver maximal system lifetime in the most challenging environments.

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