Development Platform for Self-Organizing Wireless Sensor Networks

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ABSTRACT

Distributed microsensor networks, built from collections of nodes each having the ability to sense their environment, process the raw sensor data in cooperation with other neighboring nodes into information and then communicate that information to end users. These systems are designed to be self-organizing in the sense of establishing and maintaining their own network without the need for specialist operators. In most envisioned applications, wireless communications are the most practical means of interconnection, eliminating the internode cabling. Long periods of autonomous operations in remote environments will need battery or other renewable energy sources. In order to prolong battery life, all node hardware and software functions need to be designed to consume minimal power. In general, a node will expend energy on local processing of sensor data to produce compressed *information* in order to reduce communications. These network systems are intended to support large numbers of such nodes to cover large geographic areas. This presents technical challenges in areas such as low cost design, scalability, cooperative processing and reliable operation of complex systems. Such networks are finding applications in both the military and commercial arenas, and the UCLA/Rockwell Science Center team[1] has developed a prototype wireless sensor node, "AWAIRS I," as a development platform to examine many of the issues relating to their design, deployment and usage. These issues cover a broad spectrum, from determining the best sensors for particular applications, to constructing low power signal processing algorithms and robust and low power network protocols.

1. INTRODUCTION

An important class of emerging networked systems for many military and commercial applications is distributed microsensor networks. A wireless distributed microsensor networks consists of a collection of communicating nodes, where each node incorporates a) one or more sensors for measuring the environment, b) a processing capability in order to process the sensor data into "high value" information and to accomplish local control, and c) a radio to communicate information to/from neighboring nodes and eventually to external users. In the not-too-distant future, technology will advance to the point that miniature ultra-low power CMOS chips that integrate radio communication, digital computing, and MEMS sensing components on a single die are produced in large quantities for low cost. This will permit large numbers of such devices to be easily and rapidly deployed (e.g., airdropped into battlefields) to form highly redundant, self-configuring, ad hoc sensor networks for applications such as open or urban terrain security, surveillance and equipment monitoring. For ease of deployment the nodes use wireless communications and are capable of establishing and operating their own network without the need for specialists. To prolong battery life all node functions are designed to consume minimal power. Highly capable and ultra-reliable systems will be built out of large numbers of such nodes that are individually inexpensive and use cooperation between nodes to achieve the high reliability and improve the quality of information. Our experience with current experimental sensor networks thus far developed shows great potential for robust, large scale environmental monitoring and interaction.

The Rockwell Science Center and UCLA has developed a prototype development platform for experimenting with microsensor networks under an existing DARPA TTO AWAIRS program [4]. The prototype node, called AWAIRS I, is based on an open, modular design using widely available COTS technology. To date one hundred units of the latest version of wireless microsensor nodes (see Figure 1) have been built. These nodes combine sensing capabilities (such as seismic and acoustic) with a commercial cordless telephone radio and an embedded commercial RISC microprocessor in a small package. As these networks are designed for low power, embedded signal processing is performed to reduce communication requirements. The sensor nodes are supporting experiments in multihop data communication protocols, dynamic cooperative signal processing (e.g., beamforming with randomly spaced nodes) and distributed resource management.

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To address the limited availability of microsensor network testbeds, the development platform together with associated user interfaces and development aids that can support research activities and field experiments in this domain have been constructed. The unique aspects of microsensor networks can best be examined with significant numbers of prototype devices explicitly designed for this purpose, as opposed to generic computing platforms. Some of these unique requirements include: 1) small, lightweight form factor, 2) robustness to wide temperature ranges and other demanding environmental conditions (for field experiments), 3) battery or other stand-alone power sources, 4) low power operation and access to internal power control mechanisms, 5) a small, low power, capable radio with sufficient range, 6) a real-time execution environment, 6) the ability to code in a high level language for rapid algorithm hosting and testing and 7) a reasonable cost. In microsensor networks, large numbers of devices (greater than 10) are needed to truly address issues such as scalability, spatial distribution, frequency reuse and a host of possible application scenarios. In addition, we have found it to be critical in a testbed system for these devices to have excess software and networking capabilities that support data collection exercises for algorithm developers using the actual sensors situated in field conditions. For example, higher sampling rates, wide bandwidth communication, mass storage, augmented power supply are all useful in data collection, but would add unnecessary overhead in the normal microsensor operational concept.

Figure 1: AWAIRS 1 Prototype Microsensor Node

Despite technology advances, microsensor nodes will always have limitations on computation, memory, communication, and battery resources. This precludes the use of heavyweight protocols such as TCP/IP and runtime environments such as Windows 98/NT/CE. On the surface, it would appear that supporting a Java runtime environment with downloadable applets and platform independence would have advantages in increasing the utility of sensor networks. However, with memory requirements of a Java virtual machine approaching several megabytes and a high-end CPU required for acceptable performance, it is inherently too resource consuming for a microsensor node, even the larger and more powerful prototype nodes currently in development. In the near future, the size and power consumption of microsensor node components will continue to decrease with hardware advances, but these fundamental resource limitations will remain. To make matters worse, battery technology has historically improved at a much slower pace, with no equivalent to the exponential growths experienced in computation, memory, and communication performance. Languages or scripts that support portable and mobile code will have to be tailored to the microsensor environment.

The actual development and operation of a microsensor network is a many-faceted process involving tradeoffs in system architecture, software-hardware interplay, low power communication protocols, deployment methods, configuration schemes, packaging, user interfaces, external system gateways, and more. Currently, we are in the advanced stages of our development of a second-generation microsensor system under the AWAIRS program. The previous version, mainly developed under the DARPA ETO LWIM program [5,6], was produced in quantities of about 70 devices and distributed to educational, government and commercial institutions. The current device consisting of a processor, radio, power supply and sensors (seismic, magnetic, acoustic) are also intended for delivery to multiple researchers at government, university and commercial sites. It is built entirely out of COTS components and we have developed software for the basic communication protocols, a runtime kernel, sensor drivers, signal processing applications, and user APIs that support displays for operating and debugging the system. As part of the overall concept validation process, the team has conducted numerous field demonstrations and data collection exercises in various conditions at military bases with military targets using these sensor networks. Despite the emphasis on military battlefield applications, the nodes are also being used to support the condition based maintenance of industrial and military equipment. A testbed for monitoring of motors and pumps has been instrumented with the AWAIRS 1 nodes incorporating an acceleration/pressure/temperature sensor. Signal processing algorithms are run on the nodes for early detection faults and wireless communication provides for simple installation and cooperative diagnostics.

Through our work in the distributed microsensor system domain during the last three years, we have gained practical knowledge of the issues involved with the formation and operation of sensor networks. The system we have developed is the result of considerable effort in designing, fabricating, and debugging the hardware and software to achieve the goals of ease of application programming, experimentation with network protocols and distributed signal processing algorithms and rapid interfacing of multiple sensing devices. The existing prototype node, while short of the ultimate micronode in many respects (size, power consumption and cost), captures all the essential characteristics and represents an ideal vehicle on which to base the future research in distributed microsensor networks.

2. THE AWAIRS DISTRIBUTED MICROSENSOR RESEARCH

Rockwell Science Center and UCLA are engaged in a joint research program called Adaptive, Wireless Arrays for Interactive RSTA in SUO (AWAIRS) [4] for DARPA/TTO. This research program is aimed at proving concepts underlying distributed microsensor networks such as cooperative processing and low power communication protocols [8,9]. A fundamental assumption is that the system deployment concept is based on using many expendable nodes instead of a few high value assets. Scenarios such as monitoring buildings or avenues of approach are accomplished by positioning the sensors close to the areas of interest in high densities. Close spacing permits low power sensing and short range radio links. The nodes can be precisely located or dispersed in random configurations with spatial knowledge (or lack thereof) incorporated in the signal processing and communication algorithms. This versatility makes the nodes suitable for a wide range of battlefield applications ranging from perimeter security to reconnaissance. The AWAIRS 1 wireless microsensor node, shown in Figure 1, was developed as a testbed to explore these research topics.

The sensor network must interact with the external world. Two-way communication is provided throughout the system as an essential attribute. Each node supports bidirectional, peer-to-peer communications with a small number of neighbors. Multiple portals for transporting information into or out of the sensor network can be established. A portal can be extended by allowing the connection of long-range radios to any one of the nodes (through the RS232 interface), allowing a user to monitor the network remotely. While dependent on the particular long-range radio selected, stand-off distances of several kilometers have been demonstrated. A distributed microsensor network user can issue commands through a user interface hosted on a personal computer, allowing users to control the network of nodes, including setting sensor sensitivity thresholds or field reprogramming of the nodes over the radio. The user interface can display activity at each of the sensors along with their health status. A sample user interface is shown in Figure 2 where sensor-processed information is communicated to the user and shown over a map background.

Figure 2: Sample User Interface Display

A spread spectrum radio in each node provides a robust wireless communication link. It enables data rates of 100 kbits per second over ranges in excess of 100 meters. Two-way peer-to-peer communication among nodes in a small neighborhood supports multihop data transfers, avoiding the requirement for all nodes to be in range of a base station. This feature gives users much greater flexibility in the deployment of the nodes enabling strategic sensor placement in the area of interest without the constraint of line-of-sight communications to the central monitoring site. In general, it can be shown that it is more power efficient to use small radio hops versus larger hops to cover the same distance. Power control on the radio is used to minimize the transmit power needed to communicate with its neighbors.

The networking problem in a wireless sensor network is distinguished from that in a conventional wireless data network for the following reasons:

- Although there are random aspects to the communication needs, the generated traffic patterns of distributed sensor networks are in the main predictable, allowing efficient tuning of protocols. There are predictable flows (e.g., status to portals), but events (e.g., target detections, commands) that cause messages have random spatial and temporal characteristics. Detection information is forwarded to portals, but there are many opportunities for summarization. Cooperative processing such as beamforming requires dynamic multicast groups of nodes that are closest to the events. Since targets or other phenomena that cause events can be mobile, the set of nodes that are actively sensing them will change, moving the locus of message generators.
- Nodes have extremely limited battery energy, making time-division multiple access (TDMA) schemes attractive, and requiring special routing schemes optimized for minimal power consumption.
- Nodes are relatively closely spaced, as each sensor has limited range (generally smaller than the radio range) permitting efficient multihop schemes.
- There may be a large number of redundant nodes with overlapping coverage area providing options on error control, spatially separated sensor fusion and information flow reduction.
- Nodes may have multiple sensor types (e.g., seismic, acoustic, IR etc.), each with different coverage, accuracy, and power consumption allowing local sensor fusion but complicating the network management task.
- The sensor nodes may require synchronization for time tagging of data and coherent signal processing that is implemented with power conserving, network time distribution algorithms.

The requirement for simple node deployment necessitates that the network of nodes be capable of self-discovery and self-configuration. Self-organizing procedures for bootup and automatic node incorporation into the network are being implemented. This allows nodes to be added to an operational network for improved coverage or replenishment. Mechanisms for recovering from node failures are included so that the network will be self-healing. Our approach is to build on a power-efficient, time-division multiple access scheme supporting multihop communication. We are developing new, specialized protocols for the sensor network because the point-to-point and multicast addressing and communication patterns supported by conventional computer networks (e.g., TCP/IP) are not ideal for the applications in sensor networks, primarily due to high overhead, non-real-time delivery, no inherent power management and lack of spatial addressing. As one example, routing algorithms should avoid creating “power consumption hotspots” that result in sensors in a neighborhood dissipating battery energy much more rapidly than the rest of the network causing partitions when their energy is depleted.

Research into low-power signal processing algorithms is also an integral part of the system development effort and (for battlefield applications) is focussing on the following:

- Target detection/classification - The nodes currently run seismic detection algorithms based on energy thresholding. While a simple technique, it is subject to false alarms, leading us to consider more sophisticated spectral signature algorithms. Low power algorithms to classify a detected event as an impulsive event (either foot-step or gun-shot) or vehicle (wheeled or tracked) have also been demonstrated [10,11].
- Sensor fusion - The inclusion of multiple sensors on each of the nodes enables fusion of different sensors leading to decreased false alarm rates. Algorithms for fusing the seismic, acoustic and magnetic sensors on a single node are being developed.
- Cooperative sensor fusion - Algorithms utilizing the advantages of a network of nodes span a range of cooperative behaviors, each of which trades off detection quality versus energy consumption. Examples of cooperative fusion range from high-level decision corroboration (e.g., voting), to feature fusion, to full coherent beam formation [12].

3. AWAIRS 1 DEVELOPMENT PLATFORM

The characteristics of the AWAIRS 1 hardware and software design will be detailed. The cross section of the node, showing the internal stacking of the boards, is presented in Figure 3.

Figure 3: Modular Architecture of AWAIRS 1

Modular hardware design. The hardware in each microsensor node uses an open, modular design that allows incorporation of a range of sensors. Board interconnection is provided by two 40-pin mini-connectors. The connectors form a system bus that provides power and control lines to the sensor boards, and supports multiple open interfaces such as RS232, SPI and USB. The AWAIRS 1 node consists of a stack of base circuits comprising the processor, radio and power supply, which are coupled with the desired sensors. Shown in Figure 3 is a standard battlefield node. From the top down the boards are:

- Acoustic Sensor (under development),
- DCT Digital Spread Spectrum Radio module,
- StrongARM Processor module,
- Multiple voltage Power Supply module,
- Seismic Sensor module,
- Mark 4 Products Geophone (seismic sensor) and
- 2 standard 9V batteries

The basic hardware block diagram given in Figure 4 shows the connectivity and power distribution between the major modules within the system. Table 1 summarizes the hardware specifications for the modules developed to date.

Figure 4: Hardware Block Diagram

	External Dimensions	2.75 in x 2.625 in x 3.5 in
	Internal	Stack of 5 boards, 2.25 in x 2.25 in
Processor Module		
	Processor	Intel StrongARM 1100 @ 133 MHz, 150 MIPS
	Power Dissipation	Max: <300 mW, Typical: < 200 mW, Idle: < 40 mW, Sleep: < 0.8 mW
	Memory	128 KB SRAM, 1 MB FLASH memory
	GPIO	26 lines
	Radio Interface	3 wire RS-232
	Sensor Interface	4 wire SPI and USB
	External Interface	JTAG, USB, and RS-232
Integrated Radio Module		
	Modem	Conexant RDSSS9M spread spectrum
	Data Rate	100 Kbps
	RF Power	1 mW, 10 mW, 100 mW
	Range	> 100 meters at 100 mW
	Frequency	ISM band, 902-928 MH, divided into 40 channels
	Controller	Embedded 65C02 microcontroller with 32 KB SRAM and 1 MB bootable FLASH memory
	Other	4 bit ADC for battery voltage monitoring
Power Supply Module		
	Input Voltage	4-15 V
	Output Voltages / max Current	1.5 V / 160 mA; 3.0 V / 20 mA; 3.3 V / 300mA
Sensor Modules		
	Seismic	Mark IV geophone
	Acoustic	Knowles BL1785 microphone, 4 Hz -2 KHz (in design stage)
	Magnetometer	Honeywell HMC1001, sensitivity = 1 lb of iron at 6 feet (in prototype test)
	Accelerometer, Temp, Pressure	20 KHz accel. sampling bandwidth, combined with temperature and pressure sensor

Table 1: Hardware Summary

The circuit boards are built from predominantly surface mount components on a 2¼ x 2¼-inch multi-layer, double-sided board. The boards are packaged in a $2\frac{7}{8} \times 2\frac{7}{8} \times 3\frac{1}{2}$ enclosure fabricated with a rapid prototyping technology at Rockwell, easily accommodating variations in the sensor suite. AWAIRS 1 modules have common connectors for stacking in any order. Electrical connections between modules is standardized and complies with the AWAIRS 1 bus specification given in the Appendix. In general the connectors distribute the power and ground, the sensor boards are connected to the ARM through the SPI serial interface, the radio is connected through an RS232, the radio clock is distributed, and the ARM GPIO is made available for specific purposes. The functionality, but not the physical form, of the IEEE 1451 Sensor Bus standard can be supported through this connector design.

Processor Module. The processor module, shown in Figure 5, is built around the Intel StrongArm SA1100 embedded controller [3]. The SA1100 is a general-purpose, 32-bit RISC microprocessor based on the ARM architecture [1] that is currently rated the most efficient processor (in MIPS/Watt). The processor offers a 16KB instruction cache, an 8KB data cache, serial I/O and JTAG interface all combined in a single chip. Program and data storage are provided by 128KB SRAM and 1MB of bootable flash memory. Connection with the sensor modules is easily achieved using the 4-wire SPI interface. An RS232 port has been added to the module for connection to external devices. The processor has three states: normal, idle and sleep that can be controlled to reduce power consumption.

Figure 5: Processor Module Circuit Boards (Front and Back)

Radio Module. The radio module, shown in Figure 6, uses the Conexant RDSSS9M Digital Cordless Telephone (DCT) chip-set which implements a 900 MHz spread spectrum RF communications link [2]. The chipset has an embedded 65C02 microcontroller (shown on the left in Figure 6) that performs all control and monitoring functions required for direct sequence spread-spectrum communication (12 chips/bit) as well as data exchange with the processor module. The radio will operate on one of 40 channels in the ISM frequency band, selectable by the controller. Program and data storage are provided with 32KB SRAM and 1MB of bootable flash memory. Embedded firmware has been developed to support multiple access networking with minimal ARM processor support. The board also provides a 4 bit ADC for battery voltage monitoring. The RF portion of the radio is packaged as a small multi-chip module (shown on right), interfaces to a 50 ohm helical antenna and is capable of operating at multiple transmit power levels between 1and 100 mW that enables the use of power optimized communication algorithms.

Figure 6: DCT Radio Module

Power Supply Module. The power supply, shown in Figure 7, delivers regulated outputs of 3.3V, 3.0V and 1.5V from an input voltage of 4V to 15V. The 3.0V and 1.5V supplies can be switched on or off via pins on the connector bus. Currently, the system will run approximately 15 hours continuously on two 9V batteries. Battery life will depend on the duty cycle of the particular application, but in the battlefield configuration, ten-day lifetimes are envisaged.

Figure 7: Power Supply Module

Seismic Sensor Module. The seismic sensor board, shown in Figure 8, uses a Mark IV geophone designed for low frequency detection of seismic events. The sensitivity of this geophone is about 1μg. The circuit employs an Analog Devices AD 7714 sigma-delta converter that results in a clean, 20–bit signal from 1Hz to 400Hz. Due to the sigma-delta converter over-sampling and internal low-pass filtering, the circuit is sufficiently repeatable to allow phase matching between sensor nodes to support cooperative coherent processing such as beamforming.

Figure 8: Geophone and Seismic Sensor Module

Other Sensors.

- **Acoustic Sensor.** The acoustic sensor board under design will employ a miniature microphone such as a Knowles BL1785 microphone element with a low-end cutoff frequency of only 4Hz. The maximum frequency of interest for acoustic sensor applications has been selected as 2kHz. It is desirable to preserve phase information for beamforming applications.
- **Magnetometer.** A magnetometer module has been fabricated and is being under tested as part of a related Army Research Laboratory program. It has a 10 Hz bandwidth and employs the Honeywell HMC1001. The rated sensitivity of this sensor is 27 μgauss so that it can detect 1 pound of iron at 6 feet.
- **Accelerometer.** An accelerometer board has also been fabricated and is under test as part of a related program with the Office of Naval Research. It is intended for condition-based maintenance of rotating machinery such as motors and pumps. This board includes a high-speed accelerometer (with 20kHz sampling bandwidth), combined with a temperature and pressure sensor.

Sensor System Software Architecture

In order to support experimentation and algorithm development, a flexible software environment in which applications can be written in a high level language such as C and that hides many of the hardware dependencies yet allows access to low level functions such as power control is essential . The key software functions are organized as the following layers:

- **Monitor/Hardware abstraction layer (HAL)** that will provide the lowest level routines for initialization, basic external communication, program loading and debugging and interrupt processing. A packet protocol interpreter that can route packets arriving from either the radio or the external RS-232 to internal tasks is implemented. Program loading can occur either through an attached device or through the radio.

- **Run-time environment** that runs as a real-time kernel at each node and provides the low-level distributed infrastructure for the sensor networks. The low-level controls for communication protocols as well as the sensor drivers are hosted at this level.
- **System Applications** that perform signal processing computations and higher layer network functions (e.g., scheduling, routing). Written in a conventional high-level programming language such as C, new applications may be downloaded on sensor nodess already in the field using the network.
- **User interface applications** hosted on PCs that allow to perform various tasks that interact with the sensor network. An interface for communication with the network through a portal is supported as well as display and logging of network information.

A real-time, preemptive, multi-tasking kernel has been ported to the processor module that is based on the MicroC/OS [7], and designed to run on top of the AWAIRS 1 HAL. The HAL provides the three critical assembly language functions for the MicroC/OS (real-time timer, context switching and interrupt handler). The relationship between the applications, the operating system and the HAL is shown in Figure 9, with some details of the implementation. The OS is used to schedule the applications, enforce interprocessor communication with the radio and other attached intelligent modules, control higher-level power management, control attached sensor device drivers (SPI, USB, RS232, etc), and handle network messaging and related protocol functions. The HAL provides a standard view of interrupts to the OS as well as low-level access to power management, code downloads, Flash memory programming function and JTAG debugging interface. A standard I/O function is implemented to support C-language debugging and a C-level interface for network messaging.

Figure 9: Runtime Environment Components

Figure 10 shows the overall software architecture with software entities hosted on the ARM Processor Module, the DCT Module, the Sensor Modules and a host computer (PC). Support for a long range radio is also provided. Several development tools reside on the PC and the ARM for use in software coding and debugging. We assume that users will obtain the ARM System Developers Toolkit (SDT) [1] or similar compiler in order to develop their C-based applications.

Figure 10: Overall Software Architecture

Communication Protocols: A power-efficient, TDMA scheme has been implemented as the basic link layer protocol. The TDMA scheme allows nodes to turn off their receiver and/or transmitter when they are not scheduled to communicate. A multihop routing scheme has also been implemented so that information from distant nodes can be forwarded to destination locations. The link layer protocols are built on top of the digital spread spectrum radio broadcast channel that provides a raw data rate of 100kb/s.

Power Consumption: The entire sensor node consumes a peak of 1W of power, with the processor consuming 300 mW, the radio consuming 600 mW in transmit mode and 300 mW in receive mode, and less than 100 mW consumed by the sensor transducers. Proper control of the system ensures that the peak power is rarely required. An essential capability of the devices is that they can be put into *idle* or *sleep* modes under low-level software control to increase the system operational lifetime.

4. CONCLUSIONS

The current development system for distributed microsensor network research is being used as part of several research programs and is being actively used in data collection exercises and field trials. Various research activities are ongoing on topics including alternate power sources, miniature low power sensors, low-power signal processing and alarm circuits and algorithms, low power radios and protocols, GPS-based or other position location methods and distributed control schemes.

Advanced microsensor networks will present complex and difficult-to-predict behaviors, making analytical treatment intractable and empirical testing mandatory. While simulation methods can provide some degree of performance evaluation, physical prototypes that host algorithms and react to real environmental stimuli will be far superior in advancing the work of researchers who wish to create new algorithms and interface devices. More research is needed into the basic open architecture of such systems in order to provide the building blocks for the increasingly sophisticated applications being considered for microsensor networks and that go beyond the proof-of-concept effort currently undertaken in AWAIRS.

Superficially, some of the above problems may seem similar to those being addressed in general-purpose distributed and networked computing. However, conventional solutions are not only simply too heavyweight and resource demanding for use in sensor networks but also offer computation and communication APIs and abstractions that are ill-suited to the needs of sensor applications. More research is needed into software-based methods for simplifying the development of applications tailored to microsensor networks. The prototype development platform is proving to be an essential tool in this critical research arena.

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6. APPENDIX

#	Pin name	Signal type	Comments
Power section			
1	AC_VCC		ARM core power supply +1.5V
2	AC_VCC		
3	AC_GND		ARM core ground
4	AC_GND		
5	P_VCC		Peripherals power supply +3.3V
6	P_VCC		
7	P_VCC		
8	P_GND		Peripherals ground
9	P_GND		
10	P_GND		
11	P_GND		
12	P_GND		
13	P_GND		
14	A_VCC		Sensor’s front-end (Analog) power supply +3.3V
15	A_VCC		
16	A_GND		Analog ground
17	A_GND		
18	RF_VCC		DCT radio power supply
19	RF_VCC		
20	RF_VCC		
21	RF_GND		RF ground
22	RF_GND		
23	RF_GND		
24	VCC +4.0-15V (external)		External stabilized power or battery
25	VCC +4.0-15V (external)		
26	GND		Common device ground
27	GND		
28	Overload	Digital	3.3V supply overload indicator
29	1.5 Shutdown	Digital	Shutdown 1.5V power supply
SPI - synchronous serial interface			
30	SFRM	Digital	
31	SCLK	Digital	
32	RXD	Digital	
33	TXD	Digital	
USB - universal serial bus interface			
34	UDC+	Differential	Requires 1.5K pull-up resistor
35	UDC-	Differential	
RS-232 - asynchronous serial interface			
36	RXD_R	Digital	Dedicated for radio communication
37	TXD_R	Digital	Dedicated for radio communication
38	RXD	Digital	
39	TXD	Digital	
Supplemental GPIO			
40	ARM-GPIO1		DCT Reset
41	ARM-GPIO2		Sensor1 selection
42	ARM-GPIO3		Sensor2 selection
43	ARM-GPIO4		Sensor3 selection
44	ARM-GPIO5		Sensor4 selection
45	ARM-GPIO6		Sensor1 interrupt
46	ARM-GPIO7		Sensor2 interrupt
47	ARM-GPIO8		Sensor3 interrupt
48	ARM-GPIO9		Sensor4 interrupt
49	ARM-GPIO10		Sensors shutdown
50	ARM-GPIO11		Radio shutdown
51	DCT-GPIO1		Network clock
52	DCT-GPIO2		Emergency wake-up
53	DCT-GPIO3		
54	DCT-GPIO4		
Reserved (55-62)			