TandemStack
A Flexible and Customizable Sensor Node Platform for Low Power Applications

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Abstract: Wireless sensor nodes are becoming more and more considered for a wide variety of application scenarios. But by going into real world scenarios requirements becomes more complex and must be covered more accurate. Furthermore, these requirements must be met by a development process that is driven by the factors of cost and time. Reusing components is a promising way to make such a development process more efficient. We present a flexible and customizable sensor node platform which follows the objective to assemble as few functional units as possible on a single Printed Circuit Board (PCB). The PCBs are connected by a standardized board-to-board connector, which makes a free ordering and mixture of different modules possible. We will show that by using a standardized Mote Component Interconnect (MCI) an extension as well as an adaption of a sensor node to new scenarios becomes feasible by adding or replacing single platform components. The presented sensor node platform allows a fast and inexpensive development process as it is necessary for current and upcoming real word applications.

1 INTRODUCTION

Wireless Sensor Network (WSN)s become more and more common in a wide variety of application scenarios. They are used for controlling industrial infrastructures, urban and environmental monitoring as well as home-care applications. Along with their growing use cases a flexible sensor node platform is needed to meet upcoming and changing requirements in a fast and cost-efficient way.

The flexibility of the ubiquitous Personal Computer (PC) architecture with standardized buses is an important factor for its triumphal procession. A modern PC can be easily and cost-efficiently extended or adapted to new or changing requirements by replacing or adding expansion cards. Furthermore, standardized buses open the opportunity to setup systems with components from many different manufacturers. We state that a standardized interface for mote components can reduce the development costs and time for mote's hardware and software significantly. In this paper we present a flexible and customizable mote platform that follows the objective to combine only tightly coupled components on a single PCB. The different modules will be connected by a uniform Mote Component Interconnect (MCI), which allows a new freedom in combination. We will introduce some restrictions to ensure the interoperability of modules and present concepts for routing buses or point-to-point links over a uniform interface.

In the next section we will introduce a set of more or less well-known commercially available sensor nodes. All these motes are designed for low power WSNs without real application backgrounds. But their inflexible architectures limit their application fields significantly. In the following we present our TandemStack platform. We introduce the MCI, which allows a free ordering of modules. In section 5 we compare our design with a selection of motes of section 2. Finally we describe three application scenarios where our TandemStack is already used. After that we will conclude the paper with a short outlook.

2 MOTE PLATFORMS

We can identify three different types of low power motes. The first type uses a single PCB and is equipped with the basic mote components: Micro Controller Unit (MCU), transceiver, storage, sensors and power supply. The second type offers alternative components on a single PCB and third one uses a

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multi layer design, which makes replacement of components feasible. A wide varity of all these types of motes are available.

Single PCB designs like the MicaMote platforms, TmoteSky (Moteiv, 2006), Telcos (Polastre et al., 2005) or Sun SPOT (Labs, 2010) are widely used. Mica2Mote (Horton et al., 2002) and Mica2Dot were developed at Berkeley and are commercially available from Crossbow Technology (Crossbow, 2011). Both modules use an ATMega128L MCU combined with a CC1000 transceiver. The power supply is a battery pack or coin cell that can drive the modules a couple of days in active mode. The MicaDot platform was developed in 2002 and its MCU and transceiver are a few years older. Although these types of devices are not rapidly changing like high performance CPUs, their features and electrical characteristics becomes more and more obsolete. The TmoteSky, Telcos and SunSpot designs are very similar. All of these modules are platforms that can only be extended via an expansion connector. The TmoteSky uses an MSP430 MCU and the SunSpot is equipped with a 32-bit ARM-based MCU. While the MSP430 is a 16-bit ultra low power device with outstanding runtime capabilities, the ARM device has a powerful 32-bit processing core with a Memory Protection Unit (MPU). But due to the fixed platform design both CPUs must be used with the given transceivers and power supplies. A flexible combination or MCU upgrade is not possible.

A mote design with alternative devices on a single PCB is offered by our IHPNode. It was designed as a mote for a Body Area Network (BAN) for firefighters (Piotrowski et al., 2010). In contrast to other motes it is equipped with a modern MSP430 MCU and has three IEEE 802.15.4 transceivers, a subgigahertz and two 2.4GHz modules. Furthermore, two types of local storage, an expansion header and a Universal Serial Bus (USB) interface are available. All these components make the IHPNode very flexible and useful for a variety of applications. The drawback of this solution is that an adaption to other radio bands, storage technologies or a computing power upgrade still require a mote redesign.

A flexible plug and play system is available by Coalsenses iSense modules (Coalesenses, 2011). The iSense core module is based on a Jennic wireless controller. It combines a IEEE 802.15.4 compliant radio with a 32-bit microcontroller. The core module can be combined with a number of different modules. A similar design is used by the Flex Mini Kit (Evidence, 2010) and the building block-approach (Dutta et al., 2008). But the flexibility of these motes are limited by their static core module design. A modular and flexible design in a consequent manner as presented by our approach is not given.

The Tyndall25 Mote is a flexible mote 25 mm cube design developed by Tyndall National Institute (Bellis et al., 2005). The cube design splits a mote into a series of layers with an equal dimension and interface. A node is built up from an Field programmable Gate Array (FPGA) module, which operates as core processing unit. This module can be combined with sensors, power supply and communication modules. Every type of module uses a common interface connector. The FPGA and the communication module are stack modules with connectors on top and bottom side. Overlapping connector pins on these modules are connected to allow a communication through the cube and between non-adjacent modules. The compact modular wireless sensor platform described by the author of (Benbasat and Paradiso, 2005) uses also a module stack design with a uniform electrical interconnect with dedicated lines. It defines various modules, so called panes, with an individual use, which can be combined to compact sensor node. But its modularity is limited by its predefined combination schemes. A highly flexible approach is presented by the power-aware microsensor architecture (Schott et al., 2005). It is a stackable design with a core module bus that is very close to the introduced approach in this paper. But its module compatibility is implemented by an additional switching ICs, which increases module size and power consumption. A similar design is presented by (Lymberopoulos et al., 2007). It uses a CPLD-based bus controller for connecting modules.

The available hardware designs of motes mostly use a static configuration. A replacement of a main component like MCU, transceiver or storage is in most cases not possible. The presented flexible motes are built around a uniform layer interface uses a bus controller, which increases cost, size and node's power consumption. A flexible ultra low power architecture with a uniform Mote Component Interconnect (MCI) is not addressed by any of these approaches.

3 The TandemStack

As presented in section 2 most available motes use a single PCB design. In contrast, our platform approach follows the objective to assemble as few components as needed for one functional unit on a single layer or PCB. Functional units like radio, processing core, storage or power supply are separated on different layers. All these PCBs will be connected by our predefined Mote Component Interconnect (MCI). This approach provides the opportunity to easily adapt the mote to customized requirements by designing a new module and combining this with already available modules.

A wireless node consists of at least an MCU, a power source and a wireless communication interface. Although all these components are necessary for a mote a TandemStack will be assembled on at least three separate modules. A TandemStack mote consists of three types of modules being bottom, stack and top modules. One module will usually be assembled on a single PCB, although this is not a restriction as long as the module acts as one functional unit. An overview of already implemented TandemStack modules is given in table 1.

Each TandemStack mote has at least one bottom module. This module has one (basic version) or two (extended version) MCI headers on its top side. A variable number of stack modules can be plugged onto one bottom module. Each stack module has one or two headers on its top side and the according receptacles on its bottom side. A stack can be terminated by a top module, which only has one or two receptacles on its bottom side. The second MCI connector was designed for more complex motes and can be placed on each layer. The MCI pinning is strictly predefined, which allows a free ordering of stack modules. Furthermore a mixture of single and dual connector modules in a single stack is possible with certain restrictions. Figure 1 shows the TandemStack development stack with a power supply and debugging module, a processing module as well as a radio module.

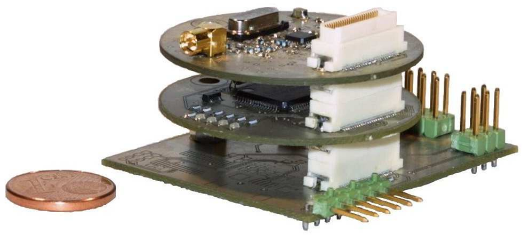

Figure 1: TandemStack development board with a power and debugging bottom module, a MSP430-based processing and a radio stack module in comparison with an one cent coin.

3.1 Configuration and Design Restrictions

In order to achieve interoperability between the modules the design of a module must follow certain configuration premises. We defined restrictions for the connector's pinning, routing and placement as well as a minimum of required features on a module.

Although Figure 2 shows a recommended outline, this is not a restriction. We think a predefined board dimension will reduce mote's flexibility in a significant manner. A designer should have the freedom to adapt the node to the application requirements instead of outline restrictions. However, for the sake of interoperability modules must follow predefined placements and pinning for the board-to-board connectors and position of mounting holes. On a stack module all header and receptacle pins must be connected (an exception are user defined pins and uni-directional pins like the JTAG chain). Furthermore the height of top side components is limited to 6mm and on the bottom side it is limited to 1.8mm. These limits are necessary to ensure that all modules can be plugged together. On top modules the top side height and on bottom modules the bottom side height of components is not restricted.

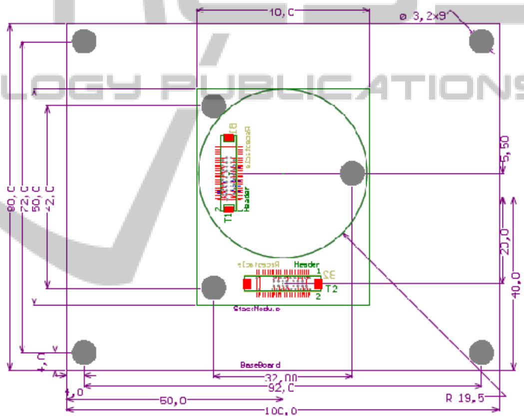

Figure 2: Dimension and placement of holes for the three different modules formats. Boards are dimensioned from the centre. Origin is the lower left corner.

Every TandemStack must have a bottom layer module. It has to source 3.3V and 5.0V supply. Furthermore, pullup resistors for e.g. I^2C and reset lines have to be placed on a bottom module. Stack and top modules must not source 3.3V and 5.0V, but may source an additional raw voltage. This way it is i.e. possible to build a solar panel power supply as a top module.

External connectors that provide communication interfaces to the stack should be placed on the bottom module. Buttons may also be placed there. Although top modules are a possible place for buttons and external connectors too, the bottom module should be preferred, because a bottom module is required in a stack configuration, while a top module is optional.

Table 1: List of already implemented TandemStack modules.

Class	Type	Device	Dimension	Connectors
Power Supply	Bottom	Thermo Electric Generator (TEG)	∅ 40mm	X1
Power Supply	Bottom	Battery supply	∅ 40mm	X1
Power Supply	Bottom	USB supply	40mm x 50mm	X1, X2
MCU	Stack	MSP430F161x	∅ 40mm	X1
MCU	Stack	MSP430F5438A	40mm x 50mm	X1, X2
MCU	Stack	Sparc V8 based LEON-2	40mm x 50mm	X1, X2
Transceiver	Stack	868MHz CC1101 radio	∅ 40mm	X1
Transceiver	Stack	868MHz CC1190 amplifier	∅ 40mm	X1
Transceiver	Top	Bluetooth Blue-SP	∅ 40mm	X1

3.2 Mote Component Interconnect (MCI)

In contrast to other configurable motes the TandemStack uses a strictly defined Mote Component Interconnect (MCI). That means each module must place its board-to-board connectors on defined positions and must use a predefined pinning. Our MCI supports a number of common mote interfaces such as GPIOs, buses, interrupt and analog lines as well as a common programming interface.

As mentioned before one MCI connector is optional (X2) and one is compulsory (X1). The optional connector X2 will be used only on layers with a larger footprint. Table 2 shows the defined pining of connector X1. Connector X1 includes all common peripheral interfaces of a typical mote. Connector X2 is an extension of X1 and provides more analog, GPIO, event, power and user definable lines. Furthermore, for specialized applications two additional power lines Vraw1 and Vraw2 and four counter lines are available on connector X2.

We use two 50-pin connectors from Hirose, which make a high-density of components possible. It has a 0.5 mm pitch and is available in a range of heights from 5 to 8 mm, which allows a tailoring of the board-to-board gap for a better matching of a required stack height. Its high pin density enables the use of highly integrated MCUs while maintaining a good mechanical stability and ruggedness.

Table 2: Pining of 50-pin MCI connector X1. The connector must be available on all layers and has s strictly defined pinning with all common mote peripheral interfaces.

Pin	Name	Type	Pin	Name	Type
1	5V0	Power	26	GPIO1	GPIO
2	5V0	Power	27	GPIO2	GPIO
3	3V3	Power	28	GPIO3	GPIO
4	3V3	Power	29	GPIO4	GPIO
5	GND	Power	30	GPIO5	GPIO
6	TEST	JTAG	31	GPIO6	GPIO
7	TCK	JTAG	32	GPIO7	GPIO
8	TMS	JTAG	33	AD0	Analog
9	TDO	JTAG	34	AD1	Analog
10	TDI	JTAG	35	AD2	Analog
11	Reset	Reset	36	AD3	Analog
12	MCLK	Clock	37	IRQ0	Event
13	MISO	SPI	30	IRQ1	Event
14	MOSI	SPI	31	IRQ2	Event
15	CLK	SPI	32	IRQ3	Event
16	CS	SPI	41	UDEF0	Udef
17	RX	UART	42	UDEF1	Udef
18	TX	UART	43	UDEF2	Udef
19	SCL	I2C	44	UDEF3	Udef
20	SDA	I2C	45	UDEF4	Udef
21	D+	USB	46	UDEF5	Udef
22	D-	USB	47	UDEF6	Udef
23	GND	Power	48	UDEF7	Udef
24	GND	Power	49	GND	Power
25	GPIO0	GPIO	50	GND	Power

3.2.1 Signal Routing

For a free ordering of stack modules all common MCI pins must be routed between bottom and top board-to-board connector. It is permitted to route pins via a module's Integrated Circuit (IC), where an IC must be active forwarder between both connectors. We call this configuration an active routing. In a passive routing configuration an IC is only connected to a static line between both connectors. Furthermore, an active routing makes a bus interruption or an isolation of stack modules feasible. Interrupting buses may be useful to operate with peripheral devices with different bus parameters, e.g. clock speed or data width. While using passive routing all components share a bus and must operate with same parameters as well as all bus members can see and influence transmitted data. For safety, dependability and security aspects an isolation of components can be useful. An active routing configuration is also useful to connect a plurality of components to a peer-to-peer link, like UART or USB.

3.2.2 Signal Types

We classified the signals used on motes in 13 different types. Most of these types are supported by all commercially available MCUs. Classifying mote signals will improve the module's interoperability. In the following we will introduce all 13 types in detail.

Power is used for a module's power supply. It includes 5.0V, 3.3V and ground lines. The Hirose board-to-board connector limits the current on single pins to 300mA. For supporting higher current modules a multiple number of power pins are defined. In addition to the basic supply voltage two Vraw lines are defined. These lines can be used with a user specific voltage.

GPIO lines are general digital input/output lines with no special properties other than being able to accept 5V even when operating on 3.3V. This restriction is true for any non-power signal.

USB lines can be used to connect ICs and/or external connectors via USB. Although USB requires a point-to-point connection and only one component can be connected to the lines D+ and D-, a USB network can be deployed over a TandemStack by using USB hubs, as shown in Figure 3. USB is strictly differenced in master and slave, so that or a free module ordering a slave must be connected to the bottom side receptacle and a master to the top side header.

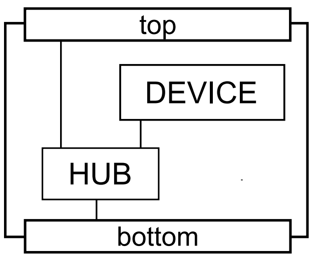

Figure 3: Routing of USB lines on a stack module by using a hub in an active routing configuration.

Event lines are a special type of GPIO lines. These lines are connected to IC pins with interrupt support for asynchronous event handling. It can also be used as a digital GPIO, if the available number of GPIOs is not sufficient.

Analog lines are GPIO lines, which are connected to an A/D converter input. In contrast to GPIO lines the signal level of analog lines is not defined and can be any value between zero and one of the stack's supply voltage. A use as GPIO line is not recommended to ensure compatibility.

Clock line can be used to deploy an IC clock over a multiple number of modules. The line is driven by a single module, normally the MCU module, and can be used by a multiple number of ICs with external clock input.

Reset line is used as a low active system reset. The signal is fed to all modules and can be used to synchronize stack ICs. A reset network can be built up by using active routing.

JTAG is the stack programming interface. It supports device chaining, which makes the number of required lines independent from the number of devices. Figure 4 shows the Joint Test Action Group (JTAG) chain in the TandemStack. An external connector must be placed on the bottom module. On each stack module the Test Data In (TDI) bottom connector pin is connected with the IC's TDI, while its Test Data Out (TDO) is forwarded to the top connector. On a top module the JTAG chain must be closed by connecting IC's TDO with the bottom connector TDO pin. By the fact that a top module is optional each stack module may have a configurable short.

UDef can be used for coupling two familiar modules. Although a strict limitation for the module's dimension is not given a module may need more than one layer to assemble all required components. In this case a module can be easily spread over more than one layer by using the user defined pins. The MCI includes 16 user defined lines without pre-defined use. Only devices, which use these pins may connect to them. The pins must be routed between both connectors and the IC. But the devices must be placed as adjacent devices, while a routing of UDEF pins is not permitted on layers that do not use it.

SPI, as most common bus interface for low power motes, is a synchronous serial data link operating in full duplex mode. Devices will be differenced in a master and a multiple number of slaves. Slaves are addressed with individual select lines. The MCI defines three data lines and one select line. Additional slave could be addressed by a GPIO line. In an active routing configuration a slave must be connected to the bottom side connector and a master to the top side connector. By using a passive routing a module can be a slave as well as a master.

I^2C is another synchronous serial data link. In contrast to Serial Peripheral Interface (SPI) I^2C uses only two lines, a data and a clock line, and is multi-master capable. These properties significantly simplify routing, but require a more complex driver software. Like all multi-master buses I^2C requires external pullup resistors for both lines. On a TandemStack these resistors are placed on a bottom module or in case of an active routing on the bus-breaking module.

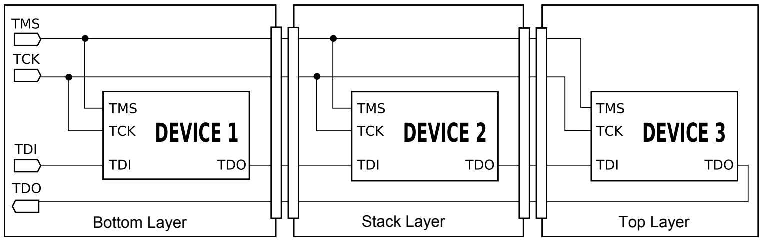

Figure 4: TandemStack JTAG chain. Devices are chained by connecting TDO with TDI between neighbored devices. The chain must be closed by a top layer module. TMS and TCK are connected to all devices.

UART is a type of asynchronous receiver/transmitter. It requires at least two lines, RX and TX, but is not a bus with a multiple number of peers. An UART link is a strict point-to-point connection with two peers. Due to this limitation the TandemStack supports in a passive routing configuration only one UART between the modules. For a multiple number of links an active routing must be implemented.

Counter lines are only available on the connector X2 and can be used as a counter input to accurately measure event timing or frequencies.

4 APPLICATION SCENARIOS

Typical application fields for motes are very wide and rapidly growing. They include sensing environmental parameters, controlling or monitoring industrial plants, buildings as well as public infrastructures. Below we describe three current examples for our TandemStack.

4.1 Low Power IEEE 802.15.4 Mesh Network

In the IQlevel project a network of observation wells for measuring the groundwater level in a drainage area should be digitalized. As main project objective IQlevel mote must operated without a permanent power supply and must be integrated in a 2-inch observation pipe. The distance among the nodes differs from 100 up to 1.500 meters and the territory changes from free field with a line of sight to forests with heavily obstructed connections. Due to these requirements and broad variation in the transmission range a flexible mote design was needed. Figure 5 shows the resulting round mote design with at least three layers and an optional CC1190 amplifier module. Besides a battery, power supply can also be supplemented by a alternative TEG module. To reduce material costs amplifiers and TEG will only be deployed with a node when its is needed.

Figure 5: IQlevel mote with battery power supply, MCU, 868MHz transceiver and amplifier module.

4.2 Research and Development

Although the basic ideas of our TandemStack were driven by the IQlevel project we realized during the project time that our TandemStack is also very helpful for testing new ICs. At the IHP various research groups are working on highly efficient mote components. Testing these devices requires a platform where single components can be replaced easily. Our TandemStack approach fulfills all these requirements better than the state of the art.

With our TandemStack topology it is possible to test new MCUs or radio baseband processors by designing a single PCB. Furthermore we can compare our devices with commercially available ones by running similar software on the devices under test. The adaptable TandemStack platform makes hardware development processes more structured and efficient and therefore more cost effective.

4.3 WSN Bridge

Low power WSNs are the main use case of IEEE 802.15.4 based radio modules. But IEEE 802.15.4 low power and mesh network capabilities make a connection to standard infrastructures more tricky and devices are rare as well as expensive. In the context of the Trusted Sensor Node (TSN) project we design a mote with an IEEE 802.15.4 and a bluetooth interface. As illustrated in figure 6, by using a TSN device a low power WSN can be connected to any bluetooth-capable device, e.g. a simple handheld device. The TSN uses an IPv4 protocol stack via its bluetooth interface to external devices, so that integration in standard infrastructures is quite simple.

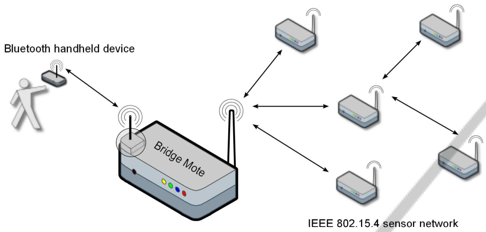

Figure 6: TSN mote as sink of a WSN, which is equipped with two different transceivers and bridges an IEEE 802.15.4 sensor network with a bluetooth handheld device.

For running complex protocol stacks the TSN mote should be equipped with a powerful 32-bit processor. We chose a LEON-2 core, which was fabricated in the IHP in house fabrication plant (fab). Besides the LEON-2 core was extended with hardware accelerators for cryptographic methods. For the bluetooth and IEEE 802.15.4 interface standard devices were used. If motes and TSN are implemented as TandemStack motes almost all layers can be reused.

5 MOTE'S COMPARISON

One important factor for the comparison of motes is their respective processing power. Especially in large scale nets with star topologies, the processing power for data sinks and bridge nodes can become a bottleneck for network performance, whereas in small scale networks this might be a waste of resources. Most mote designs have a fixed CPU that dictates its processing power. Consequently, the network's ability and structure are chosen to fit the node's abilities, not vice versa. IHP TandemStack solves this problem as single node's processing power can be suited to the network structure and can be designed to be optimal for the given challenge. For example if a star network is desired, the center node can be as powerful as the throughput demands and the single motes can implement a low-performance CPU.

Besides processing power, electrical and physical characteristics are important values for mote's usability. We compared power consumption and footprint of our TandemStack mote to five commercially available motes. The results are summarized in table 3. The TandemStack was built up with an MSP430-based MCU module, an 868MHz radio module and was directly powered by 3.3V without DC/DC converter. We can see that the smallest footprints are achieved by stacked designs. The additional mote's height is an acceptable factor as most applications have a minimal height, which allows packaging of two or three layers. Furthermore, in comparison with a TmoteSky, we see that a stacked design with its additional connectors has a few μWatts higher idle consumption only.

Table 3: Comparison of mote's footprint and power consumption.

Mote	Idle	Footprint
TandemStack	29.7 μW	40x40 mm
IHPNode	8.4 mW	50x70 mm
TmoteSky	15.3 μW	32x66 mm
Mica2	75 μW	58x32 mm
Tyndall25	60 mW	25x25 mm
JN5148	12.4 μW	30x45 mm

Another crucial point for motes abilities is their RF interface. Whereas most of them implement a single radio or a number of radios to choose from, our TandemStack can implement virtually any radio on the market. This holds true not only in single path communications, but also in multi-path designs. Furthermore, our open interface opens the opportunity to implement nodes that are not limited to ISM-band communication only. Very specialized applications such as 403 MHz medical implants, astronomical bands or even non-public bands and bridge applications between protocols and standards can be implemented.

The IHP approach therefore also solves the problem of local radio permission authorities. Most motes are limited to worldwide ISM-bands to give them the minimum common intersection set between standards worldwide. This leads to an increasing load of these few international frequencies, which makes it harder to set up a local network with standard equipment. On the other hand there are readily available radios in most countries that fit in local standards and serve bands that are usually not as heavily packed as international frequencies. The ability of the TandemStack to meet international standards as well as to inherently serve special demands of any given application makes it one of the most versatile mote solutions so far.

Compared to other standard sensor nodes, the TandemStack can be advantageous in space-limited applications while still maintaining the highest level of flexibility. Whereas the design of other motes is restricted, the modular IHP approach allows designer to start developing application on a comfortably sized development environment. At same time, as soon as application is specified, it is possible to develop a shrunk application platform, which uses previously designed and tested software. This work flow ensures highest level of flexibility and saves a lot of precious development time.

6 FUTURE WORK

The interoperability of modules is tightly coupled with a careful assignment of GPIOs. For example a multiple use of GPIO lines must be avoided as any SPI slave needs a dedicated chip select or interrupt line. Our current set of TandemStack modules is still surveyable. To keep an overview becomes more and more difficult with future extensions. A tool support will significantly simplify such a planning process. Such a tool can help to find a suitable combination of modules or selection of lines for upcoming modules.

Driven by active projects a broad set of stack modules is already implemented. Nonetheless, some modules, which are very useful in research and typically WSN scenarios, are still missing. Next steps will include the design of a storage or an FPGA module. In a lot of application scenarios a low power storage module with a capacity in the megabytes range will be needed. Flash memories with SPI or I^2C are available and fit perfectly to our TandemStack. Furthermore, an FPGA as a high performance, reconfigurable processing core is therefore very useful for development or required for massive data processing, e.g. video stream encoding. It can be implemented as an MCU replacement as well as a high performance co-processing unit.

7 CONCLUSIONS

This paper described the TandemStack platform and its Mote Component Interconnect (MCI). The TandemStack follows the objective to assemble as few components as possible needed for one functional unit on a single Printed Circuit Board (PCB). We assume that modules should only include one mote component such as MCU, transceiver, power supply, storage or sensor. Later the modules are connected by a uniform MCI. We have explained how such an interconnect can be defined for building a flexible mote platform where modules can be freely combined. We compared our design with commercially available motes and demonstrated that a stack architecture will provide the highest component density. We illustrated that in contrast to the inflexible motes our design can be used in various application scenarios with minimal development effort. We have already implemented more than nine different modules and could gather experimental results in real world scenarios as well as in research activities. We are certain that a flexible, standardized mote platform can significantly push development activities and mote deployments.

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