Poster : R-Bus - A Resource Bus for Modular System Design

Nahit Pawar
CNRS SAMOVAR UMR 5157
Télécom SudParis, Évry, France
nahit.pawar@telecom-sudparis.eu

Thomas Bourgeau
KB DIGITAL AG
Gstaltenrainweg 80, Riehen, Switzerland
thomas.bourgeau@kb-digital.ch

Hakima Chaouchi
CNRS SAMOVAR UMR 5157
Télécom SudParis, Évry, France
hakima.chaouchi@telecom-sudparis.eu

Abstract

This paper presents R-Bus, a resource bus for modular system design, that overcomes the limitations of existing approaches with flexible device integration targeted for IoT and Wireless Sensor Actuator Network (WSAN) system design. R-Bus provides a standard pluggable connection based on existing PCI-e x1 socket and connector, that allows up to 36 pins on a single bus enough to accommodate a variety of widely used embedded peripherals. We show that R-bus enhances system integration by providing sufficient resource interface with suitable pin-mapping to cope with diverse IoT application requirements.

1 Introduction

It is difficult to generalize the hardware requirements of an IoT object equipment ranging from resource constrained devices to more powerful devices used in gateways with different needs depending on the range of IoT application such as communication type, data rate, reliability, energy consumption, range, cost, security, scalability, etc. However these IoT objects are generally composed of a *processing unit* [2] that represent the “brain” in the form of ultra-low power microcontroller, microprocessor, system-on-chip (SoC), etc. that integrates a wide variety of *embedded peripherals*. This wide peripheral integration is intended to support communication interface with endless variety of general-purpose *IoT ressources* such as sensors, actuators, memory, wireless modules, etc. The number of peripherals supported and their mapping on the pins of processing unit varies with manufacturers, therefore this hardware heterogeneity can lead to different and incompatible embedded design. As a result there is a strong need and demand for *“modular architecture”* in IoT, especially during the prototyping phase and also for industrial deployment where flexibility and device evolution is required.

In the context of modular system design number of design choices already exist as shown in Table.1. These systems are generally built around a *Main-Board* containing at least one primary processing unit and one (or more) *Auxiliary-Board* containing on-board IoT Resources (sensors, actuators,...). Each of these known modular systems differs in terms of form factor and number of supported embedded peripherals with inherent limitations to cope with a large variety of IoT scenarios. In terms of peripheral diversity mikroBUS™ and Pmod only support simultaneously SPI, I2C, and UART protocols while the Grove system is restricted to a limited number of peripherals that are not simultaneously available on a single board. The limited MCUs diversity of Micro Bit restricts the possible evolution for its main board and the fixed form factor of mikroBUS™ sockets imposes to increase the size of the device by adding more modules.

This paper presents **R-Bus** a new modular system (Section 2) and evaluates its benefits through a prototype board that is compared to existing modular approaches (Section 3).

2 R-Bus

In this section we introduce a new auxiliary-board standard named R-Bus (Resource Bus) for modular IoT system design by utilizing existing PCI-e x1 connector and socket specifications [1]. The main motivation behind R-Bus system is not only to create a modular system for prototyping but also a compact and practical system to realize final IoT solutions. The main **R-Bus** characteristics are listed bellow:
Modularity : In R-Bus system, the main-board that contains processing unit, power and debug circuit is designed separately from auxiliary-board that carries various IoT Resources. The auxiliary board with PCI-e x1 connector plugs into the main-board that carries either a 90° or 180° PCI-e x1 socket. Usually an IoT system based on R-Bus can be designed with a single auxiliary-board that carries all the necessary resources required for an IoT application and therefore only one PCI-e x1 socket is need on the main-board unlike mikroBUS™, PMOD and Grove system. Furthermore, the system can be extended with additional R-Bus connectors for evolved scenarios (Gateways).

Pin-Mapping : The R-Bus connector has 36 pins (18 on each side), enough to *simultaneously* accommodate at the same time 5 widely used embedded peripherals (SPI, UART, I2C, I2S and SDIO) , upto 2 PWM (output), upto 3 Analog

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Table 1. Comparison between various modular systems

Name	Size ($w \times l$ mm)	Embedded Peripherals									
		SPI	UART	I2C	I2S	SDIO	USB	PWM	Analog	Interrupt	GPIO
R-Bus$^{\bullet}$	on going	2*	2	1	1	1	0	upto 2	upto 3	upto 3	upto 10
M2.COM$^{\circ}$	22×30	2*	1	2	1	1	1	upto 2	upto 6	$*$	upto 16
Micro Bit$^{\circ}$	43×52	1	1	1	0	0	0	upto 3	upto 6	$*$	upto 3
mikroBUS™$^{\bullet}$	25.4×57.15	1	1	1	0	0	0	1	1	1	0
PMOD$^{\dagger\bullet}$	$20.32 \times l^{\ddagger}$	1	1	1	1	0	0	upto 2	0	upto 1	upto 8
Grove System$^{\dagger\bullet}$	No Standard	0	1	1	0	0	0	0	2	0	2
Arduino Shield$^{\bullet}$	68.58×53.34	1	1	1	0	0	0	upto 6	upto 6	2	upto 20

† Not all supported embedded peripherals are available on a single board, * One SPI with two chip select signals,
$^{\circ}$ main-board standard, $^{\bullet}$ auxiliary-board standard, ‡ no prescribed standard length, $*$ no explicit mention of dedicated interrupt lines

(output) and upto 2 Interrupt signals, which is more than any other auxiliary-board standards (see Table 1).

Form Factor : Unlike mikroBUS™ Micro Bit, Arduino shields and Pmod, the exact specification of R-Bus form factor is not fixed and rely only on the fixed size of PCI-e X1 socket and connectors. This allows system designers to customize auxiliary-boards based on application requirements with more flexibility.

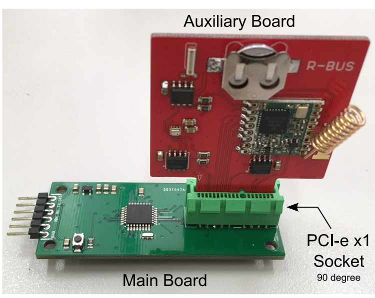

Figure 1. R-Bus : Main and Auxiliary board Prototype

3 Evaluation and Prototype

In contrast with existing well known standards, R-Bus offers the following advantages to system designers :

- It provides the possibility to realize a complete IoT solution on a single board, which is otherwise impossible in auxiliary-board standards because not all peripherals are simultaneously accessible.
- It leverage heterogeneity problems by using a fixed pin-mapping shared by any r-bus system with no additional software or application needs.
- The total number of peripherals offered by R-Bus is more than any other competing auxiliary-board standards (see Table 1))
- It offers simultaneous use of all 5 peripherals and 8 pins for general purpose interface, which is not possible with Pmod, Grove and restricted in mikroBUS™ because of form factor.
- R-Bus is not suitable in a situation where it requires fewer IoT resources, making R-Bus an overkill.
- R-Bus borrows its connector and socket from PCI-e x1 standard with proven reliability, wide distribution and inexpensive references.

Hardware Prototype : For showcasing the practical advantage and proof-of-concept of R-Bus, we consider a typical IoT scenario, where we have to design an environmental sensor node that records barometric pressure and temperature. In order to actualize this sensor node, the IoT resource use LoRaWAN technology for communication using SPI based RFM95 transceiver module. There is also an external memory (SPI based W25X40CL 4-MB flash), an external I2C based battery backed RTC (Real Time Clock), an I2C based barometric pressure sensor BMP280 and the main-board is built around an ATmega328P MCU, compatible with Arduino IDE to create and debug applications.

Although in this scenario we only used two embedded peripherals - SPI and I2C, but because of the number of IoT resources required is more (5 in this case), we need more than one auxiliary-boards for PMOD, Grove and MikroBUS^{TM} based solutions. One can easily interpolate, when the requirement of distinct peripherals increases the number of auxiliary-boards for PMOD, MikroBUS^{TM} and Grove System also increases. Also the size of the main-board increases with the number of auxiliary-boards added.

4 Conclusion and Future Work

In this paper, we have proposed a new modular system named R-Bus to cater the requirements of IoT while designing an embedded wireless sensor actuator node. R-bus poses many advantages over existing modular approaches in terms of number of supported peripherals, simultaneous access to peripherals, form factor, etc. The main drawbacks being additional cost for the connector and too many features which might introduce redundancy while designing a very small IoT object. We also built an R-Bus based hardware prototype as an environmental wireless sensor node and compared its advantages if the similar node is realized using existing modular approaches. Finally, more work is needed to adapt R-Bus system to meet further requirements of IoT and also for the widespread adoption in the IoT community.

5 References

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