University of Waterloo

THE MARCONI PROJECT

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Transparent Wireless Modem

Project Specification

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Department of Electrical and Computer Engineering
University of Waterloo
200 University Ave. W., Waterloo, ON

Aaron Cheung
Hardware Lead
00141344

Stefan Janhunen
Algorithms Lead
00057388

Vincent G. Liu
Marketing Lead
20069140

Shu Wu
Software Lead
20069140

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1. Background

Many applications require a low-speed data link in rural areas for telemetry, data acquisition, or communications and control. The distances spanned may range anywhere from less than a kilometre up to 20 kilometres or more. In regions where no data infrastructure exists, it may be impractical or too costly to install landlines for these applications. Furthermore, many existing wireless data solutions would be unacceptable either due to insufficient range (802.11) or high cost (microwave, satellite, or specialized data links).

Relatively powerful VHF and UHF FM radios exist that can transmit voice-band audio signals in the range of 300 Hz – 3000 Hz over these distances [1]. Transmitter power typically varies anywhere between 1 W to 30 W and above.

By developing a low-cost data modem that can interface these radios to computers or other digital equipment, an economical wireless data link can be established for these applications. Using off-the-shelf radios provides additional flexibility, allowing the modem to be interfaced to different radios depending upon the particular application. Providing a standard asynchronous serial data interface on the modem allows for connection with embedded computers, PCs, smart sensors, or other equipment. Figure 1 illustrates a typical application of such a modem.

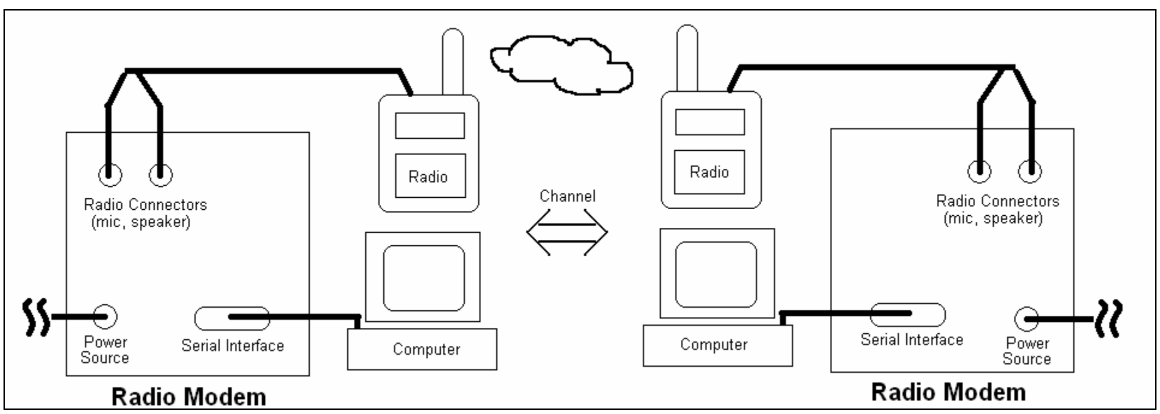

Figure 1 – System diagram of wireless data modem interfaced with radios and computers

2. Uses and Applications

User/Application	Background	Needs
Scientific researchers	Has experiments located in remote areas	Remote data must be collected; control information must be sent
Small weather stations	Unmanned data-logging weather stations	Weather data and measurements need to be recorded from stations
Industrial control/monitoring	Remote field processes/automation	Monitoring and control data must be exchanged with process at distance

3. Functional Requirements

Priority	Name	Measure	Description
MUST	Radio Interface	By design	Must work with audio interface of voice-band radios
MUST	Signal bandwidth	300 Hz – 3000 Hz	Modem output signals must fit within audio bandwidth of radios
MUST	Serial interface	By design	Must interface with other equipment over a standard RS-232 serial interface
MUST	Transparent operation	By design	Must provide transparent operation through RS-232 and behave similarly to landline modems or null-modem connections
SHOULD	Forward error correction	By design	Should implement forward error correction to reduce error rate of received data
SHOULD	Half-duplex communication	By design	Modem should be able to operate in a half-duplex mode for two-way operation over a single radio channel
SHOULD	Audio input levels	-20 dBV – 0 dBV	Should tolerate reasonable range of nominal input signal amplitudes
SHOULD	Audio output levels	-20 dBV – 0 dBV into 600 Ω	Should be capable of producing reasonable range of output signal amplitudes

4. Non-functional Requirements

Priority	Factor	Requirement
MUST	Size	PCB must be less than 25 cm in either direction
MUST	Weight	Less than 3.0 kg in weight
SHOULD	Power	Should not require over 6 VDC @ 800 mA
SHOULD	Portability	Should be small and light enough to be portable

5. Performance Metrics

The data transfer rate and bit error rate are two metrics by which the final design will be evaluated. Below are the suggested *minimum* acceptable scores for this modem. These are significantly lower than the theoretical achievable limits for the given bandwidth (300 Hz – 3000 Hz) and signal-to-noise ratio [2]. Since many factors affect the final performance (modulation scheme, radio performance, etc.), these minimums are intended only as a reference at this stage. Significantly more accurate targets supported by measurements and additional research will be presented in the Block Verification deliverable.

Metric	Target Minimum	Description
Net data transfer rate	100 bits/second	Must transfer data at minimum rate over reasonable channels (15 dB SNR per bit)
Bit error rate	10^{-3}	Must not exceed 1 bit error per 1000 bits over reasonable channel conditions (15 dB SNR per bit)

6. Unit Cost

Prototype (1-10)	Mass Production (100-1000)
< $300 CDN each	< $150 CDN each

7. Block Diagram

Figure 2 illustrates a simplified block diagram of the modem hardware, to be realized on a PCB. A highly integrated embedded DSP (Digital Signal Processor) will be used to execute the modem software. The DSP will be connected to an RS-232 interface for data transfer and to an audio CODEC interface for voice-band audio input and output. Figure 3 illustrates an initial architecture of the software modem blocks that will be executed on the DSP.

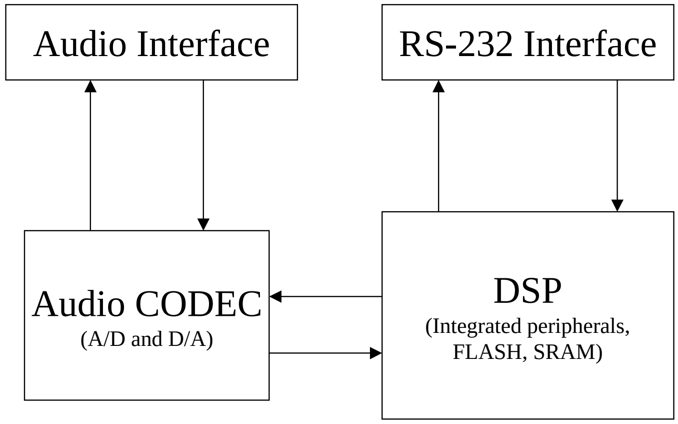

Figure 2 – Simplified hardware block diagram of modem

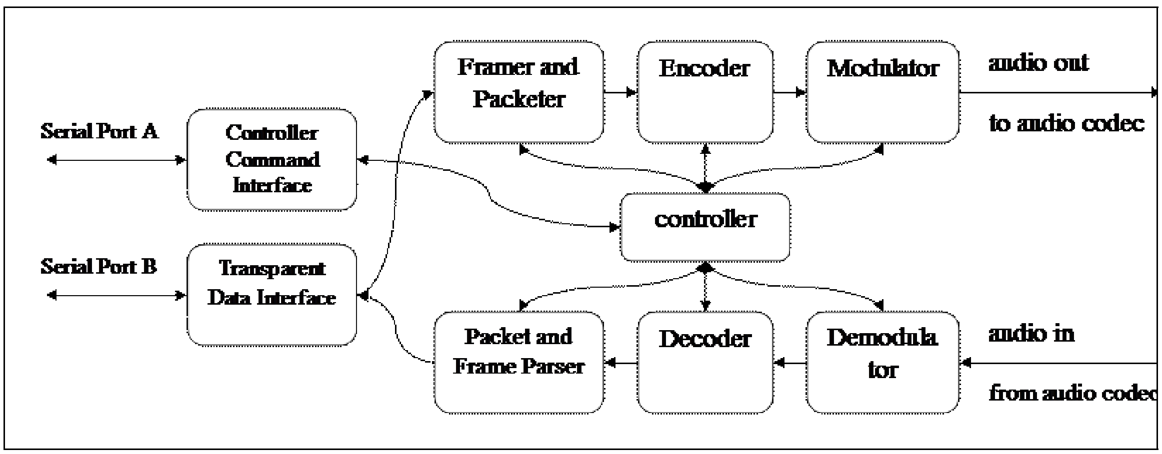

Figure 3 – Block diagram of modem software architecture

9. Risks

Level	Description	Response
High	Hardware implementation non-functional	Demonstrate modem in software simulation
High	Interfacing to voice radios problematic	Test interfaces early and choose appropriate radios
Medium	Modem has insufficient performance for required goals	Consult with advisor and perform sufficient up-front research
Medium	Insufficient memory and processing resources to implement required features	Choose embedded processor with plenty of processing power and memory to spare
Low	Hardware prototypes cannot be produced in time for demonstration	Begin work on hardware prototypes immediately

10. Plan

The milestones below represent the different phases of the project. Associated with each milestone is a well defined deliverable that should be produced by the target completion date. Each milestone is broken down into different tasks that will be partitioned among the group members (as will be detailed in the logs). Time estimates are given for each task. While each milestone has a single target completion date, work for several milestones can proceed in parallel since there is a very clean division between the hardware, firmware, and software modem aspects of the design.

Significant work will have been completed on both hardware development and firmware development by the end of the 3B academic term (as per risk analysis) in order to ensure that the first two milestones can be met successfully.

Milestone	***Deliverables***	***Target Completion Date***	***Estimated Man Hours***
Hardware development	Functional hardware	9-May-05	
Schematic design			50
PCB layout			50
PCB assembly and testing			50
Firmware development	Functional firmware drivers	16-May-06	
Develop hardware interface drivers			50

Milestone	***Deliverables***	***Target Completion Date***	***Estimated Man Hours***
Develop debug layer			20
Test drivers and debug layer			10
Research and Simulation	Block Verification	13-May-05	
Test and characterize radios			15
Research modem architecture			20
Simulate modem algorithms			50
Software modem design	Detailed Design	3-Jun-05	
Compare alternatives and choose algorithms			10
Design modem architecture (blocks)			25
Partition block implementation			5
Software modem implementation	Functional Software Modem	18-Jul-05	
Block development			100
Block-level testing (in simulation)			25
System-level testing (in simulation)			50
Hardware-implementation testing (in hardware)			25
Prototype testing checklist	Same	11-Jul-05	5
Prototype demonstration	Same	25-Jul-05	5
Experience report	Same	29-Jul-05	10
Total project man hours			**575**

11. Budget

NEED						TEAM FUND
CATEGORY	**ITEM**	**PRICE EA**	**QTY**	**UNIT**	**TOTAL**	**TOTAL**
Prototype Material					**$973**	**$973**
	PCB	N/A	5	EA	$300	$300
	DSP	$36	8	EA	$292	$292
	Parts for prototype boards (excluding DSPs)	$160	4	sets	$640	$640
	1/8" 8"x8" aluminums grounding back plane	$7	4	EA	$28	$28
	Power adapters	$5	3	EA	$14	$14
	Portable radios	$70	1	pair	$70	$70
Education Material					**$316**	**$316**
	"Wireless Digital Communications" text	$64	4	EA	$256	$256
	Practice soldering kit	$30	2	EA	$60	$60
Services					**$200**	**$200**
	Poster	$200	1	EA	$200	$200
GRAND TOTAL					**$1,489**	**$1,489**

12. References

[1] An example of one such radio is the Summation Research Inc. STR-1700. It provides an analogue audio interface to a UHF/VHF FM radio with power output as high as 35 W.
http://www.summationresearch.com/pages/products/pdf/STR-1700.pdf

[2] McDermott, Tom, *Wireless Digital Communications: Design and Theory*, Tucson Amateur Packet Radio Corporation, 1998