DICOMT SOFTWARE DEFINED RADIO FOR SEARCH AND RESCUE

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ABSTRACT

Communications Research Centre (CRC) and the National Search and Rescue Secretariat (NSS) initiated a research project to develop a prototype terminal to address the problem of interoperability and backhaul issues at crisis sites. The Deployable Interoperable Communications Terminal (DICOMT) is a software defined radio that is able to operate with a number of voice protocols, as well as with satellite backhaul. It has been designed with the flexibility to define, via software, various modes of operation compatible with the equipment first responders are expected to bring to the crisis site.

For the prototype, public safety analog AM and FM waveforms were selected, along with the digital TIA/EIA Project 25 waveform. The DVB-S waveform is used for the satellite backhaul. The DICOMT is able to choose a combination of waveforms at the site, allowing communications with other radios (using these waveforms), and also allowing communications bridging between radios using disparate waveforms.

The prototype is implemented on the Spectrum Signal Processing SDR-4000 platform, along with a Digital Receiver Technology (DRT) radio frequency (RF) front end and some CRC developed components. The CRC SCARI Software Suite was used to develop the necessary devices for the SDR-400 platform and all applications. Some special-purpose Devices were developed to support run-time selection of waveform combinations. Preliminary testing has demonstrated compatibility with commercial equipment.

1. INTRODUCTION

One of the major communications problems at an emergency site is the multiple radios protocols involved. Communications Research Centre and the National Search and Rescue Secretariat of Canada conducted research to develop a prototype software radio that would address the issue of communicating with the various radios brought by different first responders to an emergency site. This deployable interoperable communications terminal supports multiple voice waveforms along with a satellite backhaul.

The prototype terminal developed supports DVB-S for the satellite backhaul. For voice waveforms, it supports AM, FM and APCO Project 25 (P25). The waveform selection can be chosen on site and modified while the terminal continues to operate. Bridging of the waveforms is also supported allowing the DICOMT to link two or more radios using different waveforms or frequencies.

The software architecture followed the Software Communications Architecture (SCA) as specified by the US Department of Defence. Research was conducted to find ways of improving some of the limitations of the SCA, especially the ability to reconfigure waveform combinations at run-time. It was important that SCA compatibility was maintained while enhancing the capability.

Waveform Applications and Devices were developed using CRC's SCARI Software Suite of tools. Software is deployed on the Spectrum Signal Processing SDR-4000 platform, along with a supporting X86 based host running Linux. The RF interface is the Digital Receiver Technology DRT-4001. Digital IO was accomplished with a CRC developed add-in board to the SDR-4000 that enables RS-449 and GPIO connectivity directly to the user FPGA.

Other systems, such as in [2] and [3] address the integration of public safety and satellite communications using dual-mode handsets or special satellite terminals. With the DICOMT concept, the first responders do not have to procures special handsets and the DICOMT has all the software radio advantages over its lifecycle including flexibility, maintainability and upgradability.

In this paper, the DICOMT concept will be shown along with the hardware details of the prototype. The special architecture used to enhance the run-time flexibility is then examined. The waveforms supported by the DICOMT will be presented along with some of the software details such as the composition of the node. The results of testing are provided along with conclusions.

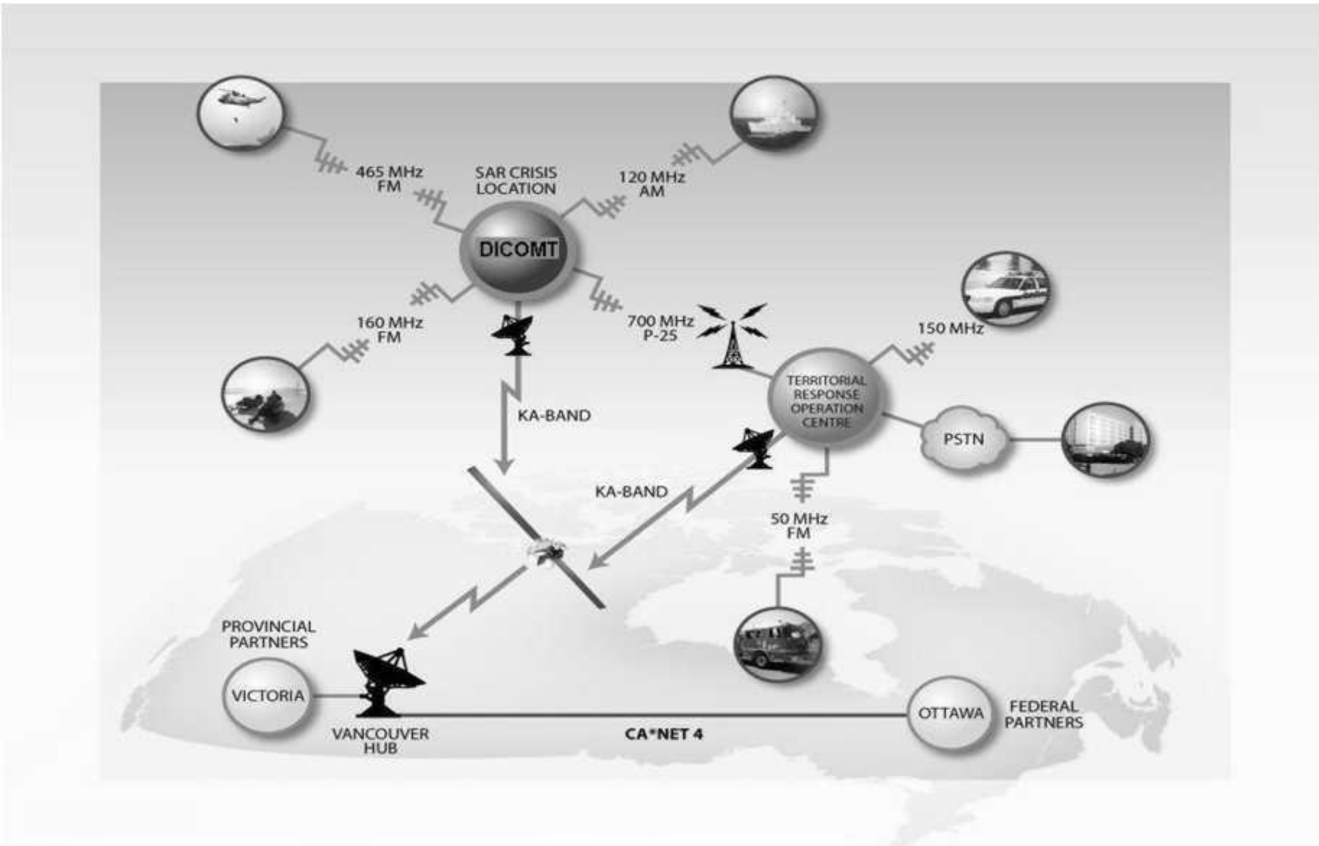

Figure 1. Diagram of a deployed DICOMT.

2. DICOMT CONCEPT

Figure 1 is a diagram of a DICOMT deployed in response to an emergency situation. The DICOMT communicates wirelessly with the various local first responders (e.g. aircraft, vessels, vehicles, individuals and teams). It also communicates with the remote operations centre using a satellite link. While the satellite protocols are likely well defined ahead of time, the actual mix of radio communications protocols is not known ahead of time (and is dependent on the type of emergency and the first responders involved). A software radio based solution allows for flexibility prior to deployment as well as changes during deployment to match radio equipment brought to the crisis area.

3. HARDWARE DETAILS

The software radio consists of the Spectrum Signal Processing SDR-4000 (for the signal processing), a Digital Receiver Technology DRT-4001 (for RF front end) and a laptop computer (for user interface, SDR-4000 host and signal processing). A CRC-built board was integrated into the SDR-4000 to allow digital IO and support an RS-449 interface.

The SDR-4000 consists of a chassis containing a PRO-4600 processing board with a XMC-3321 transceiver module. The processing board hosts a Freescale MPC8541E PowerPC processor, a TI TMS320C6416T digital signal processor (DSP) and a Xilinx Vertex 4 XC4VLX60 field programmable gate array (FPGA). The transceiver board has two AD and DA effectively sampling around 100 MHz. The transceiver board also has a Xilinx Vertex 4 XC4VSX55 FPGA that was used for up and downconversion.

The DRT-4001 provided the RF interface for all the waveforms with the exception of the satellite backhaul. The frequency of operation of the satellite exceeded the capabilities of the DRT-4001, so instead the DRT-4001 was used to provide an L-band IF interface that was connected to a standard satellite up and downconverter. Since this was a prototype developed in the lab, no amplifiers were used for the voice waveforms. Instead antennas were connected directly to the DRT-4001 inputs and outputs. This limited the range to the laboratory. Since the DRT-4001 only supported one channel in and out, a CRC developed RF box was used for the P25 waveform when it ran simultaneously with the DVB-S waveform. Additional boards could have been procured to allow the DRT to support multiple channels.

An X86-based laptop running Linux was used as the overall controller of the DICOMT. It also served as the host for the SDR-4000, served as the audio interface and served as a processor for some waveforms and devices.

4. SPECIAL ARCHITECTURE

Along with the aim of developing a prototype terminal, the DICOMT project was to investigate methods of improving the capabilities or flexibilities in a software radio. Several shortcomings of the SCA were examined.

The first shortcoming is the difficulty in implementing combinations of waveforms. If a radio is to support multiple waveforms concurrently, then the mix of waveforms must be decided at build time and cannot change at run time. For example, prior to deployment, it may be decided to support 1 x DVB-S, 2 x FM and 1 x P25 waveforms at the same time. When the emergency happens, it could be that there is a new requirement to support AM waveform for aircraft. AM cannot be added to the current mix. Someone (probably the manufacturer) would have to design a new mix that includes the AM waveform. This is too time consuming and likely would not happen in time for the crisis.

While it is possible to create many mixes ahead of time, the possible combinations require exponentially large number of waveform mixes.

A related issue is that waveforms are tied to specific ports (channels) of a device. If it is desirable to use a different port (channel) then a new waveform must be defined. When bridging waveforms, the receiver of one protocol needs to be tied to the transmitter of another protocol. Currently, this will be an additional waveform; there is no way to interconnect predefined waveforms. What is needed is a way of making and breaking connections at runtime as new waveform mixes are desired that is not tied ahead of time to a specific port.

The second shortcoming is the lack of separation between waveforms and devices. The current applications use Device connections and Device properties that are specific to certain Devices (and therefore the application is more difficult to move between various platforms). It is desirable to standardize the interface between applications and the necessary devices.

The third shortcoming is the complexities of interactions and interdependencies of devices and channels. For example, the USRP, as detailed in [1], supports multiple receive channels, but they all must have the same sampling rate. As a consequence, one application's sampling rate may be in conflict with another's. This could be resolved if there was a controller that managed the device's sampling rate and enabled different rates for different applications.

To address these shortcomings, two new devices (Platform Controller Device and Application Controller Device) were developed, and the concept of DICOMT Applications and Super Applications were created.

A DICOMT Application is an SCA Application with several differences. Where possible, the SCA Application is broken into two DICOMT Applications: one for receive and one for transmit. There are no connections between a DICOMT Application and Devices. Instead, the DICOMT Application has Reservation Request properties and Reservation Response properties, which detail the requirements for connections to Devices.

A radio runs one or more Super Applications. A Super Application is a collection of DICOMT Applications which includes the following details: DICOMT Applications to be loaded, inter-application connections to be made, and application-to-device connections to be made. All of the Super Application information is stored in a in a DSAD XML file. There is no executable part.

The Application Controller Device is responsible for loading and unloading (via Domain Manager) the DICOMT Super Applications, including making and breaking application-to-device and inter-application connections. It obtains the reservation request properties from the applications and sends them to the Platform Controller to obtain connection information. The Application Controller is controlled by a GUI and in response to commands, the Application Controller can reconfigure the Super Application to add or remove applications at runtime.

The Platform Controller Device abstracts the devices on the node. It is platform specific and has full knowledge of all the devices on the node and is solely responsible for their configuration. It responds to a reservation request by creating and configuring a port to match the application's requirements as wells as configuring the affected devices necessary to support this connection. It also supports the Application Controller in making inter-application connections. It provides frequency and power control API of RF channels. The Platform Controller allows for reconfiguration at runtime, supporting teardown of applications and setup of new application within a Super Application. The Platform Controller is very active during Super Application setup, but does very little when the radio is running. The Platform Controller acts in many ways like an Assembly Controller for the node.

5. SUPER APPLICATION EXAMPLE

A Super Application can be developed from existing applications. For this example, a stand-alone version of the AM receiver and a P25 transmitter will be combined to make a Super Application.

Figure 2 shows a stand-alone version of the AM Receive Waveform. It is made of several resources including signal detector, demodulator, and filter. The AM waveform runs on an executable device, either the PPC on

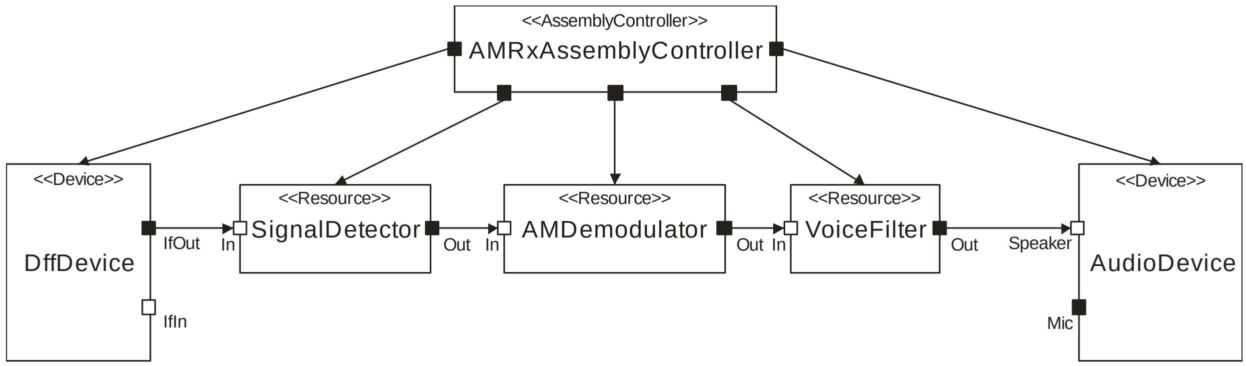

Figure 2. Stand-alone AM receive application.

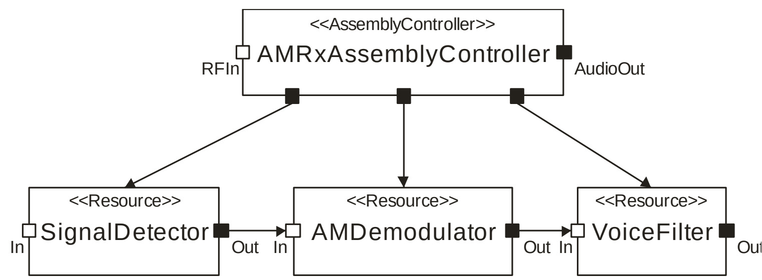

Figure 3. DICOMT AM receive application.

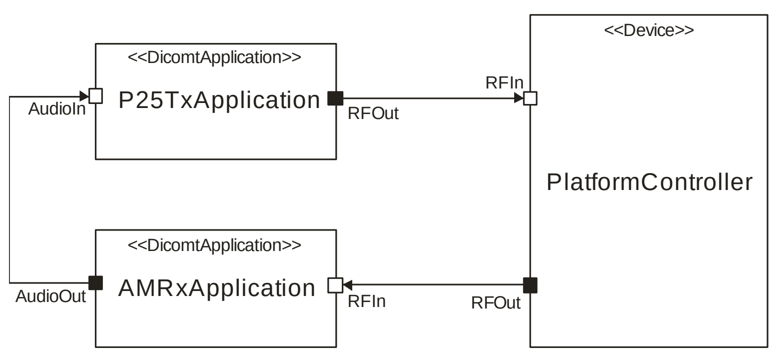

Figure 4. DICOMT Super Application AM to P25.

the SDR-4000 or the X86 on the laptop. The DFF Device in the figure represents the SDR-4000 after the digital up and down conversions. Note that because this Application includes Device connections and as such it is restricted to receiving IF data from a specific channel on the DFF Device and sending to the speaker of the Audio Device.

The DICOMT Application version is shown in Figure 3. The device connections have been removed and properties describing the requirements were added to the Assembly Controller. External ports were also added to the Assembly Controller for connections within a Super Application. These external ports are proxies for the resource ports within the DICOMT application.

Figure 4 shows a Super Application that combines the AM Receive DICOMT Application and a similarly developed P25 Transmit DICOMT Applications. Because

DICOMT Applications do not have device connections, these Applications can be connected, without modification, to other DICOMT Applications or to the Platform Controller (which proxies Device connections).

Finally, Figure 5 shows this Super Application after deployment. The Application Controller loaded the various DICOMT Applications needed for the Super Application. The connections that were made by the Application Controller are shown with dashed lines in the figure. Connections between DICOMT Applications are made with the aid of the Platform Controller. The Application Controller also made the connections from the Applications to dynamically created ports on the Platform Controller that respond to the device connection requirements of the DICOMT Applications. Also, any necessary configuration of devices is done by the Platform Controller in response to these requirements. Changes to devices at run-time (such as changing the tuning frequency) are achieved by setting properties on the Platform Controller.

incorporated into a single device because of the single-thread limitations of Spectrum's quicComm library (it is the author's understanding that this limitation has since been removed). The single device also enabled the high-speed fabric to be easily configured. The DFF Device was developed at CRC.

The DRT Device controlled the DRT-4001 and was supplied by the vendor. The PPC Executable Device was supplied by Spectrum as part of the board support package. The SCA Core Framework was that of the CRC SCARI Software Suite implemented for Green Hills Integrity and Objective Interface System ORBexpress CORBA.

The Application Controller Device and Platform Controller Device are described in section 4. They were both developed at CRC to add run-time flexibility to the DICOMT.

The user interface was based on a graphical user interface (GUI) shell developed at CRC. It was specialized for the DICOMT prototype terminal.

The development environment for the waveforms and devices was CRC SCA Architect. FPGA development was done using System Generator and Xilinx Foundation.

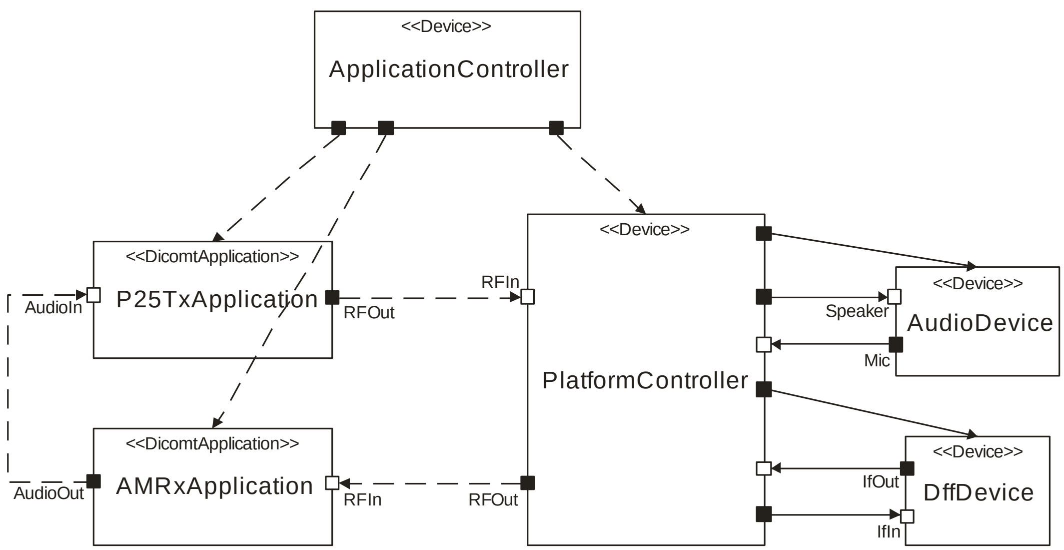

Figure 5. Deployed DICOMT Super Application AM to P25.

6. SOFTWARE DETAILS

The platform node consisted of the following devices: Application Controller Device, Platform Controller Device, Audio Device, DFF Device, DRT Device, and the PPC Executable Device. Also included in the node were the Device Manager and the Node Logger.

The DFF Device (DSP, FPGA and Fabric) was the interface for all the capabilities of the SDR-4000 platform (except for the PPC Executable Device). It was all

7. TEST RESULTS

Testing is still underway at the time of this paper's preparation. The Platform Controller and Application Controller have successfully launched a Super Application based on CRC's Audio Effects demonstration. It has proven the ability to have waveforms independent of device connections, and the ability to connect applications to devices at runtime, as well as to interconnect applications.

The AM, FM, P25 and DVB waveforms have been successfully tested in stand-alone mode. They have all been shown to be compatible with commercial equipment: Vertex Standard VXA-700, Motorola HT750, M/A-COM P7100IP and the ComStream PSK Digital Modem CM701.

The waveforms are currently being incorporated into a Super Applications and will be tested with the Platform Controller and Application Controller. It is expected that the prototype terminal will be demonstrated in the fall of 2010.

8. CONCLUSIONS

The DICOMT project has shown the feasibility and flexibility of using a software radio SCA-based solution to meet unknown or changing communications requirements at a crisis site. The novel architecture, while maintaining compatibility with the SCA, enhances the SCA to allow better waveform portability, dynamic waveform selection, and bridging of waveforms.

The hardware platform for this project has proven capable of supporting the novel architecture, capable of supporting multiple waveforms and capable of supporting satellite communications.

Results from this project are proven hardware, proven waveform applications, improved waveform development and implementation methodology, novel architecture for more flexibility, and the successfully demonstration a prototype software defined radio for search and rescue applications.

9. ACKNOWLEDGEMENTS

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