Winnebago County, Wisconsin
Local Organization of
Amateur Radio Emergency Service and
Radio Amateur Civil Emergency Service

NOAAPort Dissemination Network
System Overview

PRELIMINARY

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Table of Contents

1. Generic Sections

1.1. Revision History

Rev	*Date*	*Author*	*Change Description*
0.1	31/Oct/2007	Nick Luther	Initial draft.

1.2. Referenced Documents

Rev	*Date*	*Owner*	*Title*
0.3	25/Apr/2006	Aaron Heise & Nick Luther	RDTP/AX.25 Protocol Specification

1.3. Document Control

This document is marked with a revision and release date. Revision numbers will follow dotted-decimal syntax where a sequence of integers is joined by decimals. The most significant integer value is the left-most one. Preceding zeros will not be used. As an example, revision 1.11 is more recent than 1.5.20 which is more recent than revision 1.2.

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1.4. Confidential Information

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1.5. Acronyms and Abbreviations

- AFSK Audio Frequency Shift Keying
- AEC ARES® Assistant Emergency Coordinator
- AGWPE AGW Packet Engine
- ARES®[1] Amateur Radio Emergency Service (a program of ARRL)
- ARRL American Radio Relay League, Inc.
- AWIPS Advanced Weather Information Processing System (NWS term)
- AX.25 Amateur X.25 Protocol – widely used in HF through VHF data links
- CAE Child Abduction Emergency
- CFR U.S. Code of Federal Regulations (federal administrative law)
- CRO RACES Chief Radio Officer
- DEC ARES® District Emergency Coordinator
- DLL Dynamic Link Library – name for a shared library on Windows
- DMA Wisconsin Department of Military Affairs
- DOC U.S. Department of Commerce
- DVB-S Digital Video Broadcast - Satellite
- EC ARES® Emergency Coordinator (county-level executive)
- FCC United States Federal Communications Commission
- FTA Free-to-air (commonly used in satellite equipment circles)
- GPL GNU General Public License – an open source software license
- ICAO International Civil Aviation Organization
- LNA Low Noise Amplifier
- LNB Low Noise Block-Downconverter (note: front end is an LNA)
- LNBF LNB with feed horn
- LO Local Oscillator
- NCF AWIPS National Control Facility
- NDN Winnebago ARES®/RACES NOAAPort Dissemination Network
- NIDS NEXRAD Information Dissemination Service (or Level III data format)
- NOAA U.S. DOC / National Oceanic and Atmospheric Administration
- NWS U.S. DOC / NOAA / National Weather Service
- PID AWIPS Product Identifier
- RACES Radio Amateur Civil Emergency Service
- RDTP/AX.25 Radar data Datagram Transfer Protocol over AX.25
- RSTP Radar data Stream Transfer Protocol
- SBN AWIPS Satellite Broadcast Network, a/k/a NOAAPort
- SEC ARES® Section Emergency Coordinator (state-level executive)
- TCP/IP Transmission Control Protocol over Internet Protocol

[1] The ARES® logo and name are registered marks of ARRL.

- TNC	Terminal Node Controller
- UDP/IP	User Datagram Protocol over Internet Protocol
- UI	AX.25 Unproto Information – A datagram implementation in AX.25
- USC	United States Code (federal statutory law)
- WEM	Wisconsin DMA / Wisconsin Emergency Management
- WFO	NWS Weather Forecast Office
- WMO	World Meteorological Organization

1.6. Support of ARES®/RACES Mission

Winnebago ARES®/RACES actively participates in the National Weather Service's SkyWarn program. Severe weather spotters participating in SkyWarn stand to benefit immensely from up to date weather surveillance data. The data may also be beneficial to other ARES®/RACES served agency. This project has been authorized for these purposes.

1.7. Background

Winnebago ARES®/RACES has been developing a system to receive the NOAAPort (a/k/a AWIPS SBN) satellite broadcast since approximately 2000.[2] Significant contributions to the project have been made by Nick Luther, Aaron Heise, and Stephen Williams. The project has matured to the level where a stable set of software tools are available to receive, display, and relay via TCP/IP and AX.25 most relevant meteorological data products in the U.S. As of this writing, a system is operating in Winnebago County which receives the NOAAPort satellite broadcast and relays it via Internet to any interested members. AX.25 relay has also been tested. The system is now ready for state-wide deployment.

1.8. Scope

This document is intended as a briefing for Wisconsin ARES®/RACES personnel implementing NOAAPort Dissemination Network infrastructure, as well as for ARES®/RACES personnel who are end users of the system as user training material. Given that purpose, this document will provide a detailed explanation of the architecture of the system at a high level, and will omit any confidential information. Confidential information is required in order to implement network infrastructure, and this information will be disseminated separately.

2. The NOAAPort Broadcast

NWS WFO's, centers, and other sources transmit locally generated products via wire to the AWIPS National Control Facility (NCF). This data includes text, NEXRAD, satellite (from NESDIS), model outputs, and various other meteorological products. The data is then transmitted via air to a C-band satellite, and then transmitted back to Earth with a radiation pattern targeting the continental U.S. NWS facilities receive this broadcast and use it as a data source for products generated by other NWS facilities. The satellite broadcast is called either NOAAPort or the

[2] In the interest of avoiding self-plagiarism, the author cites an article previously published in QST on this project: *see* Luther, Nick, "Digital Dimension: Disseminating NEXRAD Data via Packet," *QST,* Sep. 2004: 81.

AWIPS Satellite Broadcast Network (SBN).[3] A graphical overview of the system is presented in Figure 1.[4]

NOAAPort has existed in some form for many year. Originally, much (if not all) of the broadcast was encrypted for the purpose of protecting exclusive data contract holders. Beginning in January 2001, NWS began broadcasting radar products without encryption. In 2005, NWS modernized the network by switching from a proprietary QPSK-based modulation to DVB-S.[5]

DVB-S stands for Digital Video Broadcast – Satellite. DVB-S receiver equipment is available for as little as $30 at the time of this writing, usually in the form of a PCI expansion card for a PC. Most cards on the market work well with a PC running a 500 MHz or better CPU core clock.

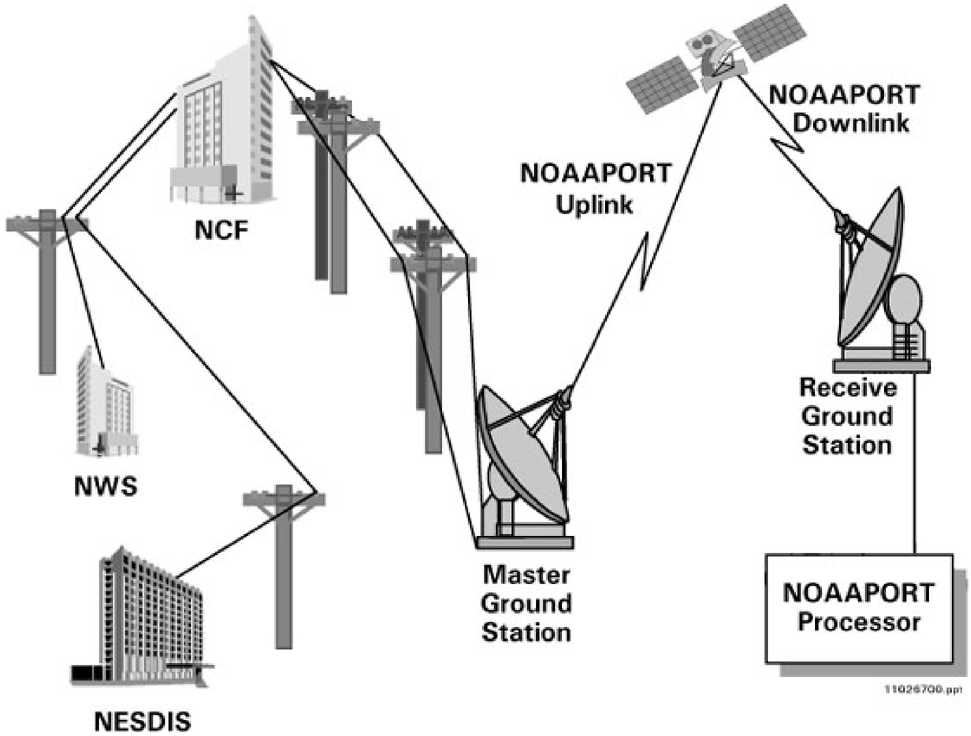

Figure 1: NOAAPort Overview Graphic (source: NOAA)

2.1. Link Parameters

The NOAAPort broadcast uses SES Americom AMC-4 C-band transponder 13C. The satellite is located at 101 degrees west longitude. In Wisconsin, this is approximately an SSW azimuth with

[3] Authoritative source: *see* http://www.nws.noaa.gov/noaaport/html/noaaport.shtml
[4] Fig. 1 source is http://www.nws.noaa.gov/noaaport/html/overview.shtml
[5] Authoritative source: *see* http://www.nws.noaa.gov/noaaport/html/history.shtml

an approximately 40 degree elevation angle. Look angle information is available via the Internet.[6] See the footnotes on this topic for links. More detailed information is presented in list form:

- Satellite: SES Americom AMC-4 (located at 101W)
- Downlink Frequency: 3956.5 Mhz
- Polarization: Vertical
- Modulation Scheme: DVB-S data (demod to UDP/IP packets)
- Symbol Rate: 6349 kS/s
- Data Rate: 10240 kbps
- Coding Rate: 7/8
- Relevant DVB-S PIDs: 101 and 102 for NWSTG and NESDIS streams
- UDP/IP destinations: 224.0.1.1:1201 and 224.0.1.2:1202 for PIDs 101 and 102

3. Satellite Receive Site Components

3.1. Satellite Dish Antenna

The only currently-operating NDN receive site is using a 10 ft. diameter, parabolic (as opposed to *offset*), mesh, dish antenna with a 60K high-grade C-band LNB and approximately 50 ft. of 75 ohm feed line. The antenna is damaged and partially obstructed, but still performs reasonably well. This site is operated by Nick Luther.

New sites should use a large diameter dish. A parabolic dish may be easier to work with than an offset dish. Because the NOAAPort broadcast uses more than 4 MHz bandwidth, it seems that most cheap, consumer-grade C-band LNBs on the market today should be sufficient (+/- 1 MHz LO tolerance is typical). These LNBs cost as little as $10 to $40. Most C-band dishes will already have an acceptable LNB and feed horn. If such equipment is needed, a possible source is provided in the footnotes.[7]

When purchasing an LNB, the important specifications to consider are noise temperature, stability / LO tolerance, and of less importance: gain and image rejection. Optimize for stability (important in this application) by choosing an LNB rated +/- 1 MHz or a smaller tolerance interval. The noise temperature should also be minimized. The noise temperature is specified in Kelvin. Some vendors and distributors will incorrectly use the term *degrees*, or even say *degrees Kelvin [sic]*. These people are infidels with respect to SI unit convention!!! Don't give in!!!

A feed horn is also required. The feed horn is the antenna for the LNB, and is used to set the antenna polarity. C-band satellites configure transponders for alternative vertical/horizontal polarities, and polarities are also configured to be opposite on the same frequency for adjacent satellites. This provides many dB of adjacent channel attenuation at the receive site, which

[6] For SES AMC-4 satellite look angle information, see http://www.ses-americom.com/americom/siteSections/satellitesAndTeleports/satelliteFleet/amc4/index.php *or* http://www.nws.noaa.gov/noaaport/html/sat_loc.shtml

[7] The author has purchased satellite equipment from and recommends (for feed horns and LNBs) Dave's Hobby Shop. *See* http://www.daveswebshop.com/satmain.shtml

translates to greater receiver selectivity. Complete LNB with feed horn modules are common on the market. The term LNBF is often used for these modules. Receive site developers may consider purchasing an LNBF to simplify system design.

Dish aiming may be accomplished with a compass, inclinometer, and L-band satellite signal strength meter. An L-band satellite signal strength meter is available through Dave's Hobby Shop (see footnotes), the local Menards store TV section, and many other retailers.

Before closing the section, some LNB (Low Noise Block-Downconverter) theory is presented for infrastructure developers new to satellite systems: The feed horn in a satellite system is a horn antenna, wave guide (feed line) and polarity selection device. The wave guide connects to the wave guide input of the LNB, where it is terminated with the LNB input. The LNB contains an LNA which amplifies the signal, then a 5.15 GHz LO (for C-band), mixer and filter. This results in an amplification and downconversion function. The LNB output is then in the L-band range. C-band refers to frequencies of approximately 4 GHz, and L-band refers to frequencies of approximately 1 GHz. The L-band signal is transmitted through a 75 ohm coax for the long-distance run to the receiver. The lower frequency of this signal reduces feed line losses.

3.2. Receiver

The modulation scheme used in NOAAPort is DVB-S.[8] DVB-S receivers are available which will convert the L-band RF signal on the coax into a stream of multicast UDP/IP datagrams containing NOAAPort data. DVB-S PCI cards are typical, which will provide a 75 ohm F connector on their faceplate for connection to the feed line to the LNB. Cheap cards are available for $30-$50. The author is currently using a Twinhan VP-1025 DVB-S PCI card which was purchased a couple years ago for $50. Consider checking eBay when searching for a DVB-S PCI card. Consider these potential purchasing errors:

- DVB-T (terrestrial) and DVB-C (cable) receiver devices WILL NOT WORK
- Old C-band receivers do not support DVB-S. THEY WON'T WORK. Just because it says “C-band” does not mean that it will work. In fact, the receiver you use is actually an L-band receiver, which is compatible with C- and Ku-band LNBs.
- Consider purchasing a DVB-S receiver card which not only supports Windows, but also Linux. A link for information on Linux-supported devices is provided in the footnotes.[9]

3.3. Receiver Processing PC

The UDP/IP datagrams from the DVB-S receiver (or receiver card software drivers) are received by special software (provided by the Winnebago ARES®/RACES NDN project) resulting in a meaningful stream of meteorological data. If a PCI card-style DVB-S receiver is used, this software may run on the same PC. A CPU with a core clock of at least 500 MHz should be used. 300+ MB of RAM and a 5+ GB hard drive are recommended for a dedicated Linux system. No

[8] For further reading, *see* http://en.wikipedia.org/wiki/DVB *or* http://www.dvb.org/
[9] For Linux-supported DVB-S receivers, *see* http://www.linuxtv.org/wiki/index.php/DVB-S_PCI_Cards

recommendations are available for Windows. Additionally, if the PC is used for other purposes, it should then be more powerful.

Once the data is received, the most convenient method for relaying it downstream is a high-speed, wired Internet connection. The satellite site may then be connected directly to the redundant Internet-based ARES® NDN network which is expected to form in 2008. Other software components, such as an AX.25 gateway, or a data archiver, may also be connected to the NOAAPort receive software.

Depending on the configuration, meteorological situation, and NWS system status, the needed Internet bandwidth varies between 0.1 to 10 kbps/kbaud. In specific configurations this bandwidth may be much higher or lower. Additionally, nodes with multiple client connections will see this bandwidth multiplied by the average number of clients connected.

4. Dissemination Network Overview

4.1. NDN System Diagram

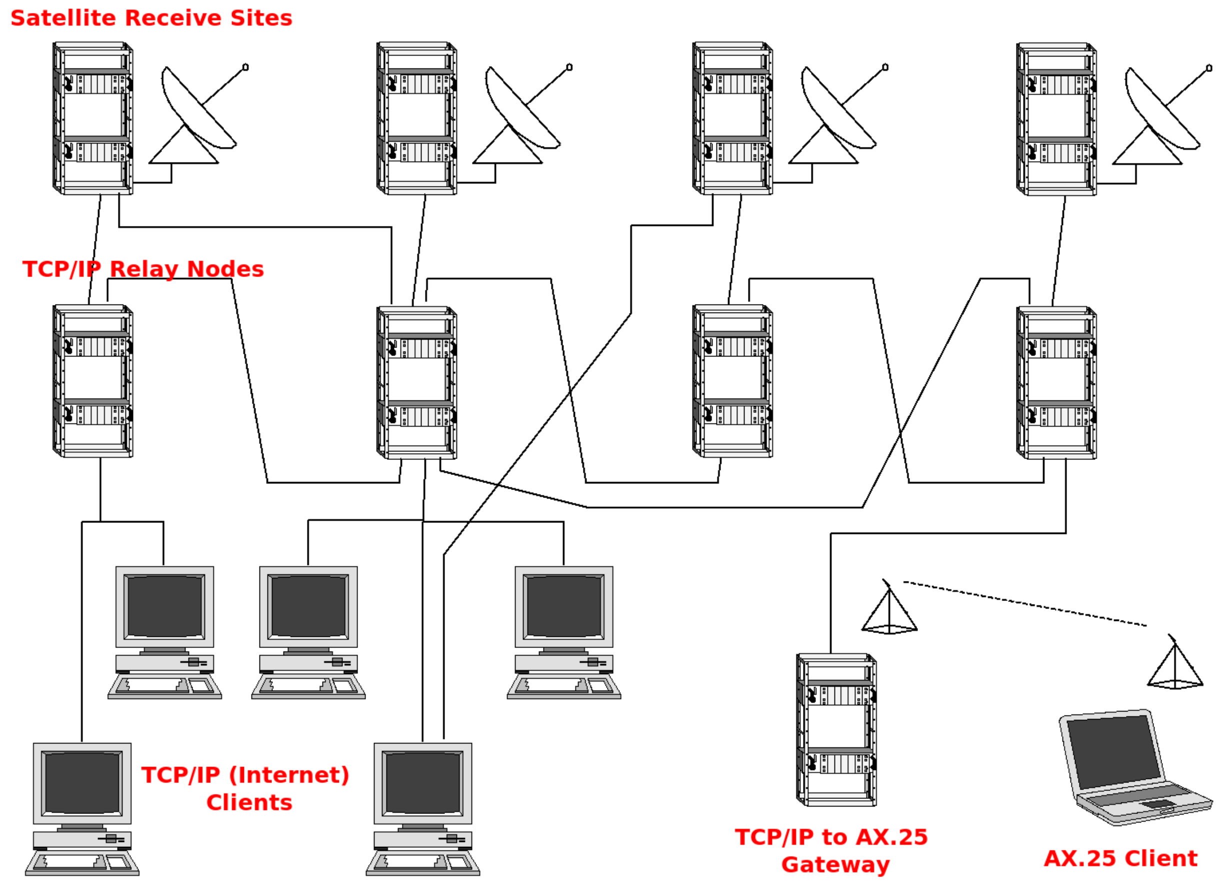

Figure 2: NDN System Diagram -- Illustrates Connection Flexibility

A hypothetical system diagram which illustrates the flexibility of the NDN is presented as Figure 2. Note especially that satellite receive sites and relay nodes can serve multiple clients, and that relay nodes and end user clients can make multiple upstream connections. At each node in the system, duplicated data products received from upstream sources will be dropped. This allows a simple scheme for redundancy, requiring only that multiple upstream connections be established. The same TCP/IP and AX.25 protocol is used for all links in the system, so an end user client may connect directly to a satellite receive site, and an AX.25 gateway may be connected to either a relay node or a satellite receive site for its data source.

4.2. Satellite Receive Sites

A satellite receive site consists of the components discussed in the "Satellite Receive Site Components" section. A PC at the receive site runs the *NPRecv* software package. This software receives UDP/IP datagrams from the DVB-S satellite receiver, and processes the data, filters the received data products against a list of ICAO/WMO Type pairs and AWIPS PIDs to accept, and then sends the data to a *libradar_stp RSTPServer* instance (hereafter RSTP Server). The RSTP Server allows for specific data streams to be defined with the same type of filter configurations, accepts TCP/IP connections, authenticates clients, and disseminates data products as they become available (a type of Internet *push* system).

A satellite receive site must have all necessary components which were previously described in this document. The *NPRecv* software operates on Windows or Linux. However, out of all of the software packages available, *NPRecv* is the most heavily restricted. It may only be used with a specific, individual license from the developer, Nick Luther, and may not be further redistributed.

4.3. TCP/IP Relay Nodes

A TCP/IP (Internet) relay node is provided in the *libradar_stp* package, which provides a common, standard implementation of the RSTP protocol). The node program is called *rstpnode*. The node consists of a redundant, multiple connection RSTP Client which feeds an RSTP Server. All of the data from the various upstream sources will be merged together, duplicate products will be dropped, and a set of data stream filters will be applied. RSTP Clients may connect to the server, the server will authenticate them via login name and password, and then the clients may request specific data streams.

Both Windows and Linux versions of the *rstpnode* program are available. The entire *libradar_stp* package is available under GNU GPL version 2 (not version 3) license. A shared library (a/k/a DLL in Windows), which is the main component of this package, provides RSTP capabilities to all other programs developed in this project which require that capabilty.

4.4. AX.25 Gateways

TCP/IP to AX.25 gateway software is a part of the *libradar_dtp_ax25* package, which provides a common, standard implementation of the RDTP/AX.25 protocol. Within this package, the *rdtpd* program provides the TCP/IP to AX.25 gateway functionality. Further filtering by AWIPS PID or by ICAO/WMO Type pair is possible at this level. Additionally, *rdtpd* provides a feature which allows data to be piped through external scripts before being transmitted. This provides a capability to strip extra radials from NEXRAD Level III (NIDS) data before transmitting it over the air. Typically, all but 90 degrees worth of radials are stripped, cutting the amount of data which must be transmitted by 75%.

The entire *libradar_dtp_ax25* package works on both Windows and Linux, and is available under GNU GPL version 2 (not version 3) license. A shared library (a/k/a DLL in Windows), which is the main component of this package, provides RDTP/AX.25 capabilities to all other programs developed in this project which require that capability. On Linux, *libradar_dtp_ax25* (and the applications making use of it) access the TNC or radio through the Linux kernel AX.25 stack. On Windows, access is through the AGW Packet Engine (AGWPE).[10] In either case, KISS TNCs, soundmodem (soundcard packet), and a handful of other, specific TNC types are all supported.

4.5. RDTP/AX.25 Protocol Discussion

The RDTP/AX.25 protocol is designed for a single server and multiple clients to coexist on a single frequency. Data streams are defined at the server. Clients only speak when spoken to, or when they have not heard any traffic for approximately one minute. Clients request specific data streams by name from the server. If the server is active, these requests are only made when the client is polled. Active clients will be polled by call sign to prevent collisions. The server either accepts and acknowledges or denies data stream requests, and transmits this information over the air for all clients to hear. No client will repeat a request for a data stream which has been recently requested. In a typical configuration, only one server and one client will ever transmit. All other clients will just listen, unless the first client falls off the air, in which case another client will take over.

No connection is ever formed. There is simply a concept of active clients. All data is encapsulated in AX.25 UI frames. Polling takes place any time after a data product has been transmitted without a poll following it, and no additional data is queued for transmission. Previous client requests will be dropped after a reasonable grace period has expired. Thus, a client must re-request its desired data streams at each poll. Recall that all but one client will simply verify that the server has acknowledged the desired data streams, and will only transmit if no acknowledgment is heard.

The RDTP/AX.25 protocol incorporates bzip2 compression by specification. A 50% compression ratio is typical for NEXRAD Level III (NIDS) data. When compression is combined with sufficient radial stripping, leaving only 25% or 90 degrees of the radials in a radial product, the transmitted data is approximately 12.5% of the size of the original, received Level III data. Most radar frames are only 2-3 kB when transmitted, which, along with protocol overhead, requires approximately 30 seconds to transmit over a typical 1200 baud AFSK VHF packet link.

4.6. End-User System

A software package called *RadarGUI* is available for end user graphical display of meteorological data. *RadarGUI* supports most types of NEXRAD Level III data, most types of GINI data (from GOES satellites), and text products. Loop and zoom features are available for the graphical displays. Additionally, most formats of polygon data in use for SPC outlooks, discussions, and watches as well as WFO-issued warnings may be graphically plotted. This feature is especially useful when receiving data off an AX.25 link in the field.

RadarGUI links to *libradar_stp* for RSTP client functionality, *libradar_dtp_ax25* for RDTP/AX.25 client functionality, and a custom library called *libnnids2* for graphical

[10] For more information on AGWPE, or to download the software, *see* http://www.elcom.gr/sv2agw/agwpe.htm

meteorological data processing support. As such, both Internet TCP/IP connections, as well as AX.25 connections through the Linux kernel AX.25 stack or AGWPE are supported. *RadarGUI* is licensed under GNU GPL version 2 (not version 3) and available for both Windows and Linux. However, *libnnids2* is licensed in separate GPL and non-GPL versions. The non-GPL version which is available to ARES® NDN infrastructure deployers includes features which have been removed from the GPL version.

RadarGUI is intuitive to use and allows for simple entry of connection/data source information. Once configured, connections may be established through a couple quick mouse clicks. Members of Winnebago ARES®/RACES have found *RadarGUI* to be reasonably intuitive and easy to use.

4.7. Archiving, Automated Alerts, and Special Applications

libradar_stp allows for custom applications to be easily developed in C++. Winnebago ARES®/RACES has deployed weather data archives, automated watch/warning alert systems which call member cell phones, and a handful of other special purpose, custom applications using this library. This software is available to ARES® NDN infrastructure deployers who would like to implement similar services in their jurisdictions.

4.8. Currently Received & Relayed Products

A full list of products currently being handled is outside of the scope of this document. Additional products may be easily added. To show the capabilities of the system, a short list is provided:

4.8.1. NEXRAD Level III (NIDS) Data

- Base Reflectivity – lowest four levels (0.5 to ~3.5 degrees elevation)
- Base Velocity – lowest two levels
- Storm Relative Mean Radial Velocity – lowest four levels
- Base Spectrum Width – handled occasionally if there is interest
- Composite Reflectivity
- Multiple precipitation products
- Long-range base reflectivity – useful for a regional view
- Free Text Messages – site outages

4.8.2. NESDIS GINI Data

- GOES-12 11 micron, 4 km (TIGE02)
- Water vapor and other wavelengths handled occasionally

4.8.3. Text Products

- SPC convective outlooks, mesoscale discussions, convective watches, etc.
- WFO-issued warnings
- Various WFO-issued severe weather-related statements
- Forecasts and various other non-severe weather-related statements
- Amber Alerts / Child Abduction Emergencies (CAE) are relayed if transmitted by NWS

4.9. Software Availability

All of the NDN software discussed herein is available from Nick Luther. As of the time of this writing, some public versions of various software components are available at http://nyquist.k9nl.net/wxsoft/. However, full-featured versions of the software packages for ARES® NDN deployment are not available to the public. Contact Nick Luther for more information.

Of course, operating systems, AGWPE, the Linux kernel, the Linux libax25 library, and other libraries linked to NDN software are all credit to their respective developers.

5. Conclusions

The NDN software discussed herein is the result of many years of hard work. A stable suite of software packages is currently available to implement the entire system. System hardware costs are very reasonable. A mature NDN deployment in Wisconsin will benefit all ARES®/RACES personnel in the state, so this state is actively encouraged by the author. Any questions will be entertained, and deployment support will be gladly provided by Nick Luther. Contact is easily made via email to <luthern at msoe.edu>.

Thank you for your interest in this project!