SWS	Space Weather Station, an effort from HamSci to build a distributed radio network for atmospheric scientific research.
P4G	Phase 4 Ground, an open source broadband microwave multiple-access radio network for amateur radio. Implements DVB-S2/X on the 10GHz downlink and an FDMA 4-ary MSK on the 5GHz uplink.
TAPR	Tucson Amateur Packet Radio, a non-profit devoted to advancing the digital arts in amateur radio.
ORI	Open Research Institute, a non-profit dedicated to open source hardware and software solutions in amateur radio, especially in the open source amateur satellite service.

Who and What

Introduction

Space Weather Stations are networked radio stations that implement one or more of the sensors discussed in the HamSci Space Weather Station project. Diverse in geography, architecture, and capability, there is a need for an internetworking protocol and philosophy to unite them. Very similar needs are shared by the Phase 4 Ground network. This document contains functional requirements work applicable to both radio networks.

Mission statement: A successful distributed radio network must be reliable, scaleable, and maintainable.

Required Functions

Remote Command and Control Function

Stations need to be controlled remotely.

For SWS: First, to schedule recording of particular events. Second, to allow rapid reconfiguration based on updated parameters from the centralized machine learning models. Third, to ensure the secure remote operation of the station. Unauthorized access or transmission must be prevented.

For P4G: First, modes where communications access to a limited resource such as a satellite need to be controlled, such as during emergency communications or for experiments. Second, to ensure the secure remote operation of the station. Unauthorized access or transmission must be prevented.

Remote Command and Control Functional Requirement Statement

Each station accepts one or more command and control connections. These are cryptographically authenticated.

Distributed Radio Network Flexibility

Stations in the network can be source of radio information, a consumer of radio information, or both. Stations should be able to connect to multiple receivers and multiple transmitters in order to carry out their experiments.

The heterogenous nature of the hardware anticipated means that some stations are less capable than others. This puts limits on the amount of connections that can be supported and maintained at each radio.

The number of receiver and transmitter connections supported depends on the capability of the hardware. Receive-only stations accept zero transmit connections. Transmit-only stations accept zero receive connections.

Each radio maintains information on capabilities and availability.

A multicast implementation that allows subscribers has been proposed.

Distributed Radio Network Flexibility Requirement Statement

Each station accepts zero or more receiver connections. Each station accepts zero or more transmitter connections.

Transmissions connections work only if authorized and authenticated.

Time Resolution

For SWS, observations of the ionosphere are radio reflections from the ionized layers of gas. The sizes of the structures can be as small as single-digit meters in size.

Sensitivity and spatial resolution are increased by using a phased array. Stations can reveal cross sections of the ionosphere if multiple receive and transmit signals can be cohered into a phased array. For phased arrays to be effective, the integration period must be limited to the time over which the phase of the signal (compared to a reference phase) does not change. This lowers the effective sampling rate and lowers the Nyquist frequency.

The repercussion is that we need nanosecond accuracy and stability in the clock edges. Variance needs to be low as well. Calibrating the variance between clocks involved in phased arrays needs to be discussed and accounted for so that variance won't dominate as a source of timing error.

This clock scheme does not need to be in the base unit, because P4G (and any other project that uses the data engine) does not need SWS levels of clock accuracy. A modular approach dramatically increases the number of potential customers for the radio, as the more expensive clock circuits are optional for many non-SWS applications.

For Phase 4 Ground receive, the DVB-S2/X specification has a phase noise mask. This sets the acceptable amount of phase noise at a series of offsets. The phase noise mask comes directly from the DVB-S2 and DVB-S2X specifications.

For Phase 4 Ground transmit, the scheme is frequency division multiple access. The uplink is channelized. Occupied bandwidth and channelization is flexible. The most straightforward polyphase filter bank applications have the number of channels as a power of two. Anticipated first deployment is to use all of the 10MHz satellite or experimental terrestrial sub-bands. Ideally, the 10MHz would be divided into segments of approximately 100kHz per channel. At 64 uplink channels, the channels are 156,250Hz. At 128 uplink channels, the channels are 78,125Hz wide. Based on observations from the Phase 4A amateur radio satellite (Es'Hail2), 128 uplink channels is a good starting point. Uplink clock stability requirements depend on the receiver in the payload.

Time Resolution Requirement Statement

The base unit must be able to accept an external clock source.

External clock source for SWS needs to have 3.3nS timing accuracy in order to resolve structures 1m in size.

External clock source for Phase 4 Ground downlink must meet the phase noise requirement in the DVB-S2/X specification (available for free from dvb.org). Uplink clock must be good enough to achieve channelization and be successfully received. Stratum 3 has been proposed.

Stratum 3 has three frequency stability specifications.

Free Run (±4.6 ppm/20 years Stratum 3 and 3E)

Holdover (±0.37 ppm/24 hours for Stratum 3 and ±0.01 ppm/24 hours for Stratum 3E)

Drift (in a lab environment: ±0.04 ppm/24 hours for Stratum 3 and ±0.001 ppm/24 hours for Stratum 3E)