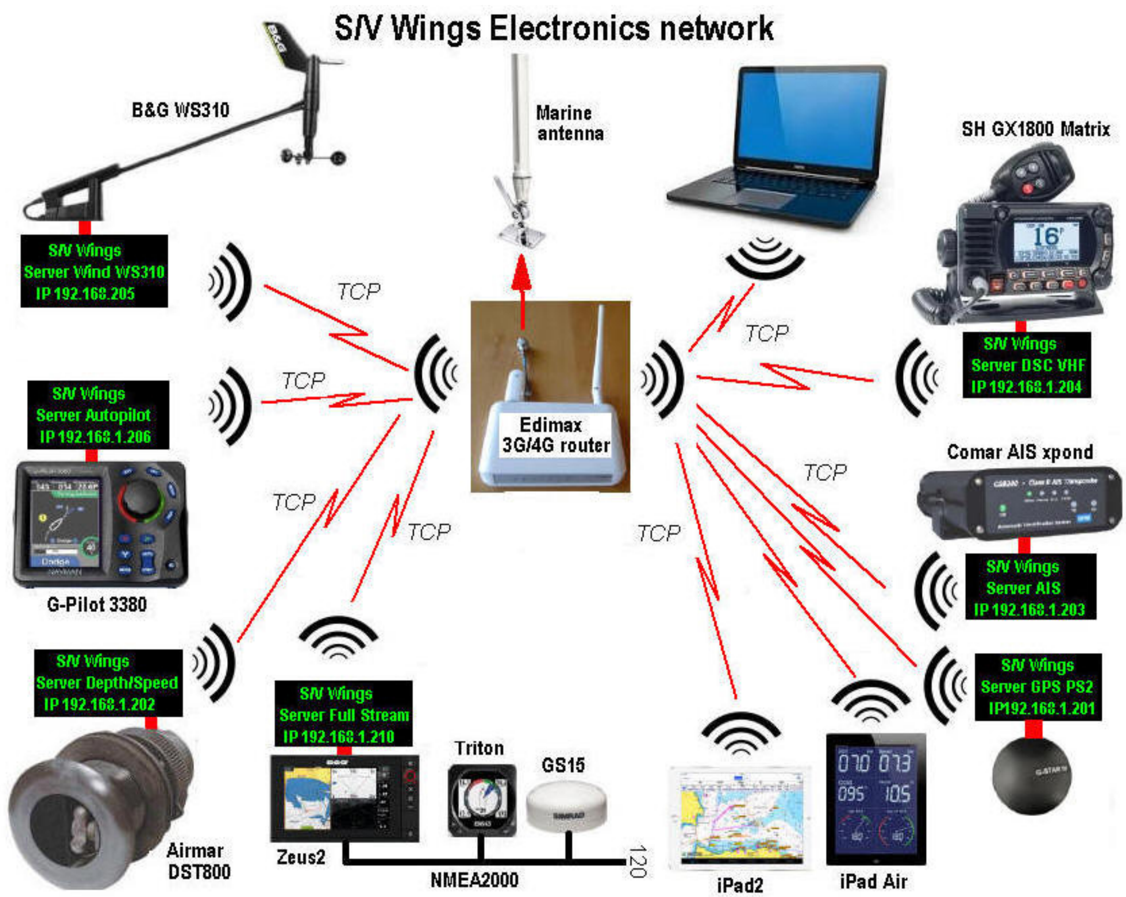
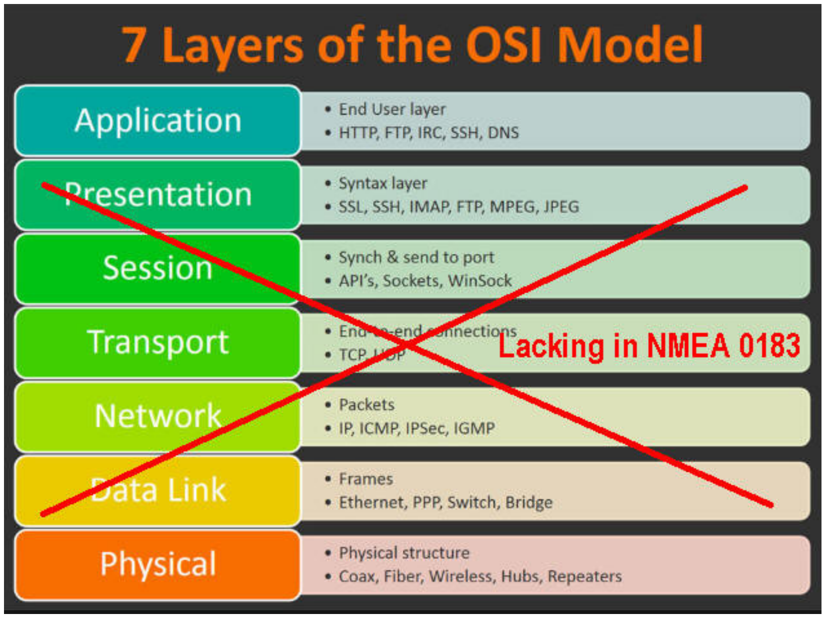
S/V Wings Electronics Network



The electronics network of S/V Wings is for the most part Wifi/Ethernet/TCP based, with NMEA 0183 data sentence definitions at application level. NMEA 0183 over TCP has become a de facto standard since it is easy to implement in mobile device apps and computers. The 0183 ASCII/CSV data format is easy to read which makes fault finding relatively simple. To be clear, we're not talking here about NMEA 0183 as an "marine electronics networking protocol". NMEA 0183 as defined by the National Marine Electronics Association is a basic 2-level protocol (physical and application levels) and networking options, as required for today's marine electronics integration, are rather limited unless extra hardware, such as **multiplexers** are used. However, NMEA 0183 sentences are well defined and there is no reason why the well proven ASCII/CSV data format cannot be used as the highest (application) layer for Ethernet/TCP networking. Data types for marine instruments have not changed much over the years and there is ample coverage for all instrument data in 0183 data sentences.



NMEA 2000 is based on the 25 year old CAN bus standard for the automobile industry and although the products of many marine electronics manufacturers are now N2K complient, it has a number of disadvantages for use on sailboats, the most important ones being the bus-topology, binary data encoding, non-independent layer-structure and cost of special cables. The much heralded "plug 'n play" connectivity promise is not quite what one would expect in practice. Fault finding at sea is difficult. N2K often cannot be avoided, but rather than using N2K for all networking its use can be limited to interfacing of small instrument clusters with bridging to more suitable and more cost effective networking.

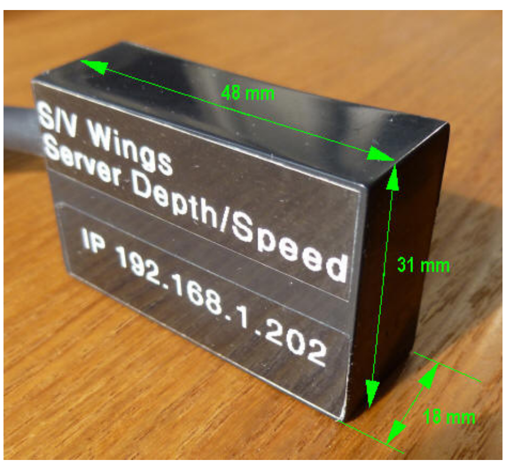
For today's marine electronics networking on sailboats the best choice is Ethernet/TCP, with low-lost off-the-shelf available networking components such as routers and interface modules. Where cabling is required instead of wifi, low-cost CAT5 network cabling can be used with standard RJ47 connectors, which are also available in waterproof versions. POE (Power Over Ethernet) is a conveneint method for powering remote sensors and network equipment. The star network topology of Ethernet is most suitable on sail boats, with simple to implement back-up mechanisms.

S/V Wings

Type of boat: Davidson designed 45 feet fibreglass blue water cruiser.
The brief for the electronics revamp was to install as little extra cabling as possible and to incorporate some existing equipment to limit costs. Full integration was required, meaning that data from all sensors, GPS and AIS should be available on computer, tablets and existing chart plotter and ample redundancy had to be built in.The design should allow seamless integration of a Simrad 4G radar in the near future. High priority was given to backup systems that can easiy be activated under difficult circumstances while at sea.

The concept.
The central node in the network is a 3G/4G wireless router. Each instrument is interfaced to its own mini Wifi TCP server. With the low cost of this kind of hardware today, the total cost of these mini-servers is roughly the same as a single multiplexer, but without the disadvantage of elaborate cabling, hence significantly reduced installation costs. All network traffic is via the router and all instruments, computer and tablets connect to the router AP (Access Point) automatically when power comes on or after an interruption.
The amount of data traffic through the network is such that only a fraction of the available bandwidth is used. Future connection of the Simrad broadband radar won't be a problem. Computer and tablets use DHCP for IP address assigment, instrument mini-servers have been configured with fixed IP addresses within the subnet. In coastal waters, the router connects to cell networks via a marine antenna with wide frequency support (2G/3G/4G for Cellular, PCS, AWS and LTE), so computer and tablets can have internet access without changing AP.

The mini-servers are Wifi TCP servers and allow bi-directional data traffic. For example, the Auto Pilot mini-server transmits 10Hz heading data (HDG) to clients and accepts navigation and wind data for GPS-mode or vane-mode steering. Clients in the network can pick the instrument data they need by opening a TCP session for each host they require data from. The mini-servers are fully waterproof with all electronics encapsulated in silicon. Multiple TCP sessions are supported.



The computer is a HP W10 laptop at the moment, but may be replaced by a fixed low power consumption computer in future. MiniMAC with bootcamp may be a candidate.
There are no cable connections other than power, so the laptop, normally in fixed position at the chart table, can be used anywhere on the boat while at anchor.

OpenCPN plays a very important role in the system. In "settings>connections" a separate client is defined for each mini TCP-server. OpenCPN has excellent features for filtering and prioritizing and besides being the main navigation application, it also functions as a traffic control centre, in a similar way a multiplexer does.

Data Connections

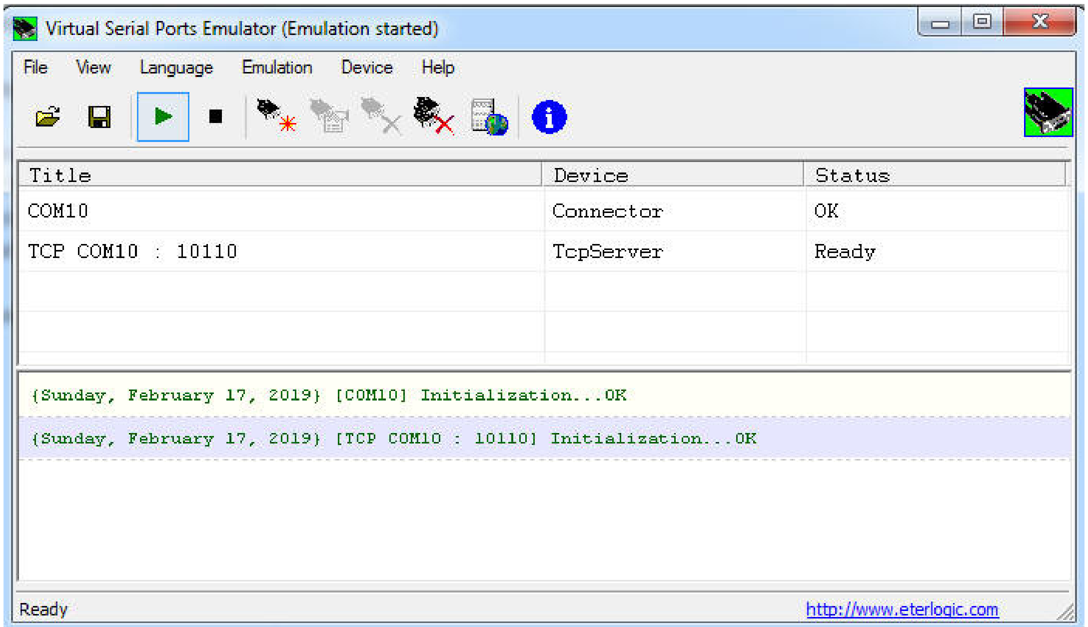
Enable	Type	DataPort	Priority	Parameters	Connection	Filters
☐	Network	192.168.1.201:10110	3	TCP	Input	In: Accept RMC,GGA,GSA,GSV, Out: None
☑	Network	192.168.1.210:10110	2	TCP	In/Out	In: Accept RMB,APB,XTE,BOD,BWW,BWR,BER,APA,BWC, Out: None
☑	Network	192.168.1.202:10110	1	TCP	Input	In: Accept DBT,DPT,MTW,VHW,VLW, Out: None
☑	Network	192.168.1.203:10110	1	TCP	Input	In: Accept RMC,VDM, Out: None
☑	Network	192.168.1.204:10110	1	TCP	In/Out	In: Accept DSC,DSE, Out: Send RMC
☑	Network	192.168.1.205:10110	1	TCP	Input	In: Accept MWV, Out: None
☑	Network	192.168.1.206:10110	1	TCP	In/Out	In: Accept HDG, Out: Send RMB,RMC,APB,XTE

Data Connections

Enable	Type	DataPort	Priority	Parameters	Connection	Filters
☑	Network	192.168.1.210:10110	2	TCP	In/Out	In: Accept RMB,APB,XTE,BOD,BWW,BWR,BER,APA,BWC, Out: None
☑	Network	192.168.1.202:10110	1	TCP	Input	In: Accept DBT,DPT,MTW,VHW,VLW, Out: None
☑	Network	192.168.1.203:10110	1	TCP	Input	In: Accept RMC,VDM, Out: None
☑	Network	192.168.1.204:10110	1	TCP	In/Out	In: Accept DSC,DSE, Out: Send RMC
☑	Network	192.168.1.205:10110	1	TCP	Input	In: Accept MWV, Out: None
☑	Network	192.168.1.206:10110	1	TCP	In/Out	In: Accept HDG, Out: Send RMB,RMC,APB,XTE
☑	Serial	COM10	1	57600	In/Out	In: Accept RMB,APB,XTE,BOD,BWW,BWR,BER,APA,BWC, Out: None

In the near future Navico 4G broadband radar will be added to the system, so the OpenCPN radar plug-in will be added.

Another program that starts up automatically is good old VSPE. The defined VSPE devices are "TCP server" and "connector". The connector is a virtual COM port (port10). In addition to selectively receiving and transmitting data from/to the mini-servers, OpenCPN also sends all data to the COM10 virtual COM port. This means all data is available via the VSPE server on the computer as a combined data stream from all sources. External clients such as the 2 iPads and other single-client devices access this server on the PC via the router and receive the full data stream of all available data in the network. No special Windows settings for networking are required, but for client access to the VSPE server the Windows firewall settings had to be changed to allow traffic for the VSPE app. Clients such as iNavX or iSailor on the iPads need to know the host IP address. As the computer uses DHCP, its IP address will not always be the same and as a result client connections to the VSPE server may sometimes fail. This has been resolved by mapping the computer's mac address to a fixed IP address in the router. This is a common feature found in most routers.



Special mini TCP Servers
Most TCP servers are identical, except for IP address setting and baudrate for interfacing the sensor. However, there are 2 mini servers with special features:

1. The PS2 GPS server
This unit has a PS2 connector for connection of a PS2 GPS. 5V power is supplied to the GPS via PS2, so GPS with mini server forms a very compact wifi-accessable GPS solution. Normally external clients receive data from the VSPE server, but It may also be accessed directly as a backup GPS if other equipment fails. There are 3 other GPS's present in the system and the PS2 GPS is primarily intended as a backup.

2. The "full stream" server.
OpenCPN sends all available data to this server, which is the dedicated mini server for the B&G Zeus2 chartplotter. The Zeus2 receives all data from the network from this server via its NMEA 0183 port, including AIS, and can return nav data, such as APB for auto pilot GPS-mode control. The full stream server is no different from the other mini-servers, but has a loop-back switch which can be activated when the Zeus plotter is turned off. The full data stream can now be accessed by other clients. It has the same function as the computer-resident VSPE server.

B&G Zeus2 chart plotter (a recent addition)
Together with the Triton instrument and GS15 GPS, the Zeus2 forms a small N2K network. At the time of purchase, there were no plans for an Ethernet/TCP based network and the owner was told by an electronics sales consultant that N2K was the way to go with future additions N2K compatible. One factor that played a role was the option of adding broadband radar in future. This uses the Ethernet port of the Zeus2.
The "full stream" mini TCP server described above is the Zeus2 dedicated server.
The Zeus2 is only used during manual steering and is switched off most of the time on long passages. The 2 iPads are the main navigation devices in the cockpit, on brackets mounted under the spray dodger.
The Zeus2 takes care of the 2-way bridging to the small N2K network.

B&G WS310 Wind sensor.
Although the mini-server has sufficient wifi range for mast-top installation, for practical reasons it has been installed near the mast foot, inside the cabin, together with terminals for other mast cabling. A thin 4-core cable carries the seriel data from the WS310 MTU and supplies power. Wind direction and speed are displayed on one iPad with NMEA Remote and on the other in iNavX. When the Zeus2 chartplotter is switched on, all instrument data is bridged by the Zeus2 to N2K and wind data can be displayed on the Triton instrument primarily while the boat is steered manually.

Airmar DST800 (Depth Speed Temp)
This is a new addition. The old (Seatalk1) depth sounder has been de-commissioned. the mini-server for the DST800 has been installed inside a bunk, <1m away from the DST800, connected via a serial cable that carries the NMEA signal. Installation in the bilge would have been possible, but the current location is just as convenient and is always dry. The old Seatalk sensor cable has been used as power supply cable to the DST800 and mini-server.
The same applies to the depth/speed/temp sensor as for the wind sensor: display on iPads and/or Triton and Zeus when Zeus is on during manual steering.

Comar CSB200 AIS transponder (SRT-based) (most recent addition, second hand). Dedicated VHF aerial on bimini.
It is a good principle to always purchase basic instruments for a particular function, with as few bells and whistles as possible. So in case of AIS transponders, no integral wifi, no USB, no internal splitter or dedicated display. All additional features can be potential fault-sources and have often been added to the original design as add-ons to increase functionality for marketing purposes.This applies to the S/V Wings network in particular, where wifi is available through the mini-servers. Integral wifi often doesn't offer the features and flexibility required for the networking as described above. Also, why have a dedicated AIS display if there are already a computer and 2 tablets on board with excellent s/w for AIS target display and collision warning.?

On S/V Wings, the AIS internal GPS is used as the primary GPS for navigation, with the GS15, the internal Zeus W9 and the PS2 GPS as backups.

Standard Horizon GX1800 Matrix
This DSC VHF radio requires GPS input and outputs a DSC/DSE NMEA sequence when a DSC Call is received. Like the other sensors and instruments, both in-and output is via wifi and its dedicated TCP mini-server, mounted on the back of the VHF unit with Velcro.

GPS use and backup
The GPS from the Comar AIS unit is usually the primary GPS input when the Zeus2 plotter is switched off. If on, The GS15 GPS received via the full stream server is the primary, with the internal W9 as backup, as it is for the Zeus2 itself. The PS2 GPS can be used as primary when AIS and Zeus are switched off.
A new model Globalsat BR355 with Glonas support has been ordered to replace the current Haycom, which will be keps as spare.
The iPads can connect directly to the PS2 GPS mini server if all other equipment is switched off.

G-Pilot 3380 Auto Pilot
Although the auto pilot functions autonomously in compass mode, it is interfaced to the network via its own dedicated mini TCP server. 10Hz heading from the fluxgate compass is fed into the network to be used by other equipment. If a

waypoint or route is activated in OpenCPN or iNavX on one of the iPads, nav data and auto pilot control data (RMB and APB sentences) is delivered to the auto pilot for GPS mode (=track mode) steering

iPads
Tablets are increasingly discovered by the boating community as good, cost effective alternatives for dedicated marine instruments and chart plotters. On S/V Wings the iPads are both wifi-only models and are used as navigation and instrument displays in the cockpit, in waterproof covers and most of the time fixed to brackets under the spray dodger. OpenCPN on the Windows laptop at the nav station inside the cabin is the main navigation app, but iNavX is often used for checking position, navigational hazards and AIS targets, sometimes also for track mode steering control of the auto pilot.
When the Zeus plotter and Triton instrument are not switched on, one iPad with NMEA Remote app is used as large instrument display.

Individual power switches.
Power to each instrument/sensor/mini TCP server is individually switched, so non-essential instruments can be switched off on long passages when navigating in DC economy mode.

Endurance tests
The complete system has been continously tested for many days and nights and is extremely stable. Auto recovery and backup switching has formed an important part of testing. If any of the mini servers, instruments, router or computer are switched off at any time, auto-recovery takes place within seconds without manual intervention when power is switched back on.

Fault finding
An easy method for checking if all is working correctly is by watching the OpenCPN debug window, which shows the active IP addresses. If client sessions with mini-servers fail, this is indicated by the easily detected red text in the debug window.

All mini servers in the network can also be accessed individually outside (and simultaneously with) OpenCPN by running a terminal program such as Teraterm. An instrument-specific Teraterm log can file can be created for analysis later on.

Carried spares
Besides spares for auto pilot and other essential parts, network spares that are carried are:

Router, with identical configuration as the one in use. In the unlikely event of router failure, all that needs to be done is plugging the 12V power cable into the spare unit and swapping the 4G USB modem. The system recovers automatically. The cost of a wireless 4G router is typically around $50.00, so this is not a large investment for keeping a spare on board.

Mini TCP servers (2).
In spite of robust design, all electronics including mini-servers can fail. 2 spares are kept on board. Configuraton with computer or one of the iPads is easy via the internal web pages. Easy to follow instructions have been supplied.

Computer.
If/when the laptop is replaced by another computer, the laptop will be kept as spare, identically configured as the main computer for easy swapping.

iPads
There are 2 iPads on board, simultaneously in use, but with the same apps installed. If one fails, full functionality is still available on the other, so they are each other's backups.

Other technical features
By configuring port forwarding and DDNS (Dynamic DNS), the router can be set up to allow another vessel or shore based station to access all or selected data in the S/V Wings instruments network via 4G.
The S/V Wings router is not configured for this at the moment. Possible applications are real-time fleet position tracking, remote AIS target tracking and remote diagnostics.