

WHITE PAPER

MARINE ELECTRONICS

How to build your own boat network and Wi-Fi - Complete with internet access and NMEA data bridged from your boats NMEA network

CONTENTS

Contents.....	2
Introduction	3
The THINGS YOU NEED	5
First build a WIRED NETWORK (Ethernet).....	9
Adding a Wi-Fi network	11
Adding an NMEA Gateway device	12
Adding a 4G router to the boat	12
How NMEA over TCP/IP works	14
Additional things to plug in.....	17
A Quick Network 101 for Beginners.	21
Key Findings	28
Conclusion.....	29



INTRODUCTION

NMEA networks are great. They are robust and provide all the information you need on your boat ... unless you want radar or modern forward-looking sonar, or video feeds from the mast for docking or to connect modern collision avoidance, AI systems, or to connect night vision cameras through the network, or you want to have access to tablet navigation systems or ... well you get the idea.

A full speed TCP/IP network on your boat is becoming a necessity and more importantly opens a lot of new opportunities for boaties. It can allow use of low-cost high value tablet and PC based NMEA software such as:

- iSailor
- iNav
- Navionics
- NMEA Remote
- qtVLM
- OpenCPN
- Etc.etc.etc.

A Wi-Fi network connected to this network opens even more opportunities and breaks down so many barriers that are inherently part of proprietary marine systems. Although the purpose of NMEA was to create interoperability, it falls short of this target quite badly.

The factor is timing. In the IT world, standards took time and slowly were demanded by consumers and for a while there were pseudo standards. Eventually rigid coherent standards were adopted and if you wanted to play in the park you needed to make sure you played within the rules.

The problem with NMEA, is that by the time it reaches this level of standardisation, faster networks based on existing technology will have taken over. TCP/IP is coming to your boat sooner or later.

But how hard is it to get a boat network setup? How do you get NMEA onto that network and connect a cheaper, built more easily, maintained chart plotter, or connect tablet plotters etc?

The purpose of this White Paper is to demonstrate that this isn't hard to do, and it is something you should consider investing in.

Here are a few reasons to consider why you need a TCP/IP based network on your boat.

- To add a separate chart plotter to your boat so you have redundancy in navigation will cost you upwards of £4000, or you could build your own for a less than £400 if you have a network to hook into. You can also subscribe to an android or iPhone app such as iSailor, iNavX, or even Navionics for a fraction of the cost and get cheaper faster updating maps to boot.
- You can add more flexibility in your boat electronics suppliers
- Access to open-source software
- Access to 4G and mobile networks
- The ability to keep watch from your bunk
- More standardisation at lower costs
- To some degree future proof against changing standards that are mostly software based.



THE THINGS YOU NEED

To build a boat network (TCP/IP) you need:

- A server or device that will provide DHCP and DNS services (more about these later)
- At least one wired router so you can attach more than a single device
- Some cabling (CAT 6 ethernet cabling)
- **Optionally** a Wi-Fi router (this can be the same as the wired router)
- **Optionally** a NMEA to ethernet gateway (bridge) so that you can receive and transmit NMEA data onto your TCP/IP network.
- **Optionally** a 4G router so you can connect it all to a mobile network

All these components are just purchase items i.e., you don't need to build them because you can simply walk into a store or alternatively order them online

We are also NOT talking about a lot of money. Unlike proprietary NMEA networks where a single cable can cost you \$100 or more, CAT 6 will be a fraction of the cost and even the server component of this equation can be purchased new for less than \$100.

I'll outline my choices for this build guide but there are other options, some of which I'll cover as I have also road tested that as well, before settling on the design I chose.

Network DHCP server

This is just a simple computer that can allocate addresses for your network. You can build a network without one, but it will mean you have to manually enter the network configuration into every device, including your iPhone et al. Therefore, a DHCP server is a good idea.

This can be a simple device, something you already have or even a plug and play DHCP server device. The cost is usually less than \$100. Most WAN routers have a DHCP built in, as do most 4G routers. You may well find you already have one, even your MFD probably has one already built in.

Routers

Standard routers connect devices on your network. A completely simple network would just connect two computers using a CAT 6 cable and manual configuration on each... but you couldn't plug in anything else. Routers solve this problem and are quite cheap and reliable. See: **The Role** of a DNS server

DNS stands for Domain Name Server and it is effectively a computer, or more accurately a network of computers that hold a phone book of data that maps a Domain Name, what is known as a Fully Qualified Domain Name (FQDN) and is human readable, like www.SailingWaiata.com into a network IP address that computers use to talk to each other and TCP/IP knows how to route.

So a query to a DNS for www.SailingWaiata.com would return the IP address of 139.59.161.151 (The IP address of our website).

DNS servers are in a network so if one doesn't know the answer it will forward the request to another one until it either gets the answer or fails. If it fails you can't contact that service.

So to be clear, when we setup www.SailingWaiata.com we had to go to the DNS authority for our Domain Name supplier and update the "Phone book" listing (Called an A record) for the IP address for this domain and this address would then be sent out over the DNS network so it would be fast to find.

About routers

CAT 6 drop cables

These are just the cables that connect things together. You have probably seen these on your home network or at work. They are cheap, compared to proprietary marine cables and available everywhere. You can use a CAT 6 cable up to 100m without any form of signal booster etc. So mostly on a boat you'll just need cables and routers.

BTW, we call them 'drop' cables because they are often coming from the router to your computer on your desk as a drop, they don't need to be connected, it won't stop the network working, just the device it was supposed to be connected to.

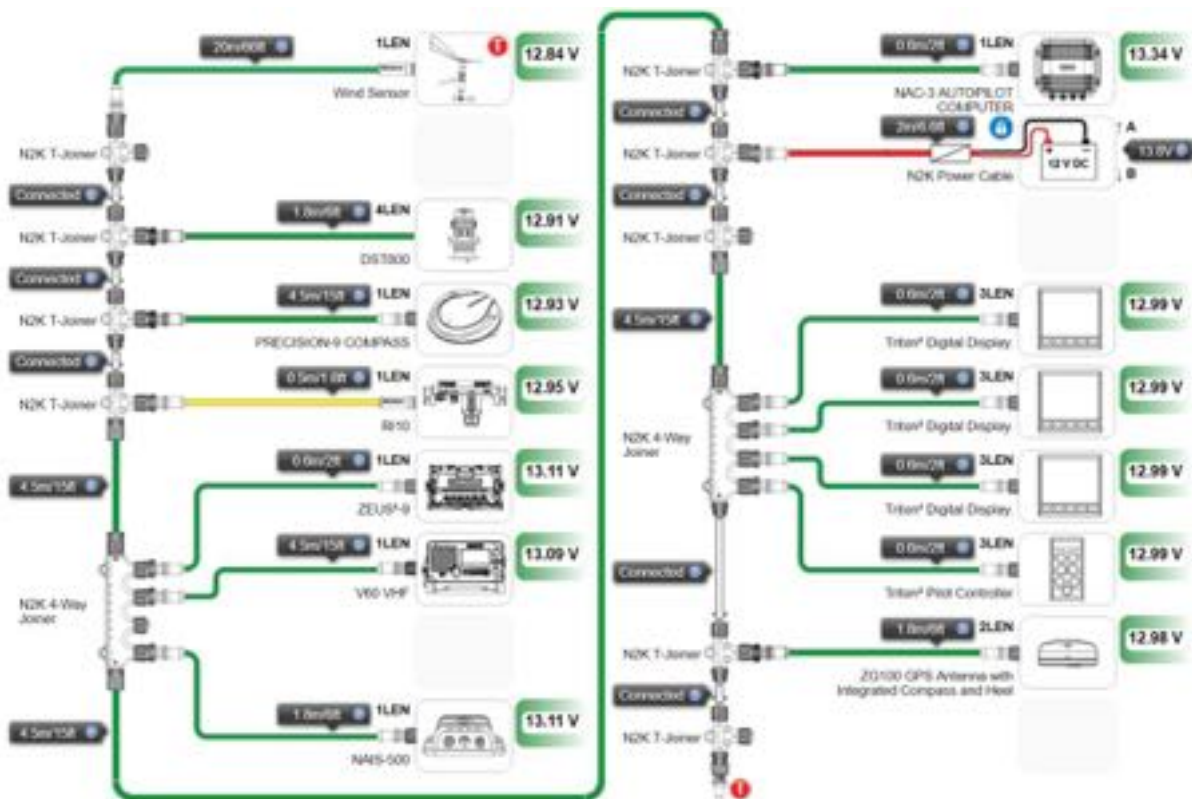
THE MOST IMPORTANT THING YOU NEED IS A HOLISTIC VIEW OF WHAT YOU ARE BUILDING

The networks on your boat are not complex. When you draw your NMEA network out, it is quite simple and so will be the case with an Ethernet network. If you don't get a view of how you are going to put it all together it can be confused and messy, which results in complications.

It is best draw out your plan and know where you are going to put the different components and how you might join the networks together.

The diagram below outlines my NMEA network design that came with my boat. It's almost exclusively NMEA2000 and includes a Zeus 3 16" touch screen MFD at the helm. It did not include a navigation station inside the saloon.

To this I added a B&G 4G radar and forward-looking sonar which both had ethernet cables connecting directly into the Zeus MFD at the helm so were separate from the NMEA network.



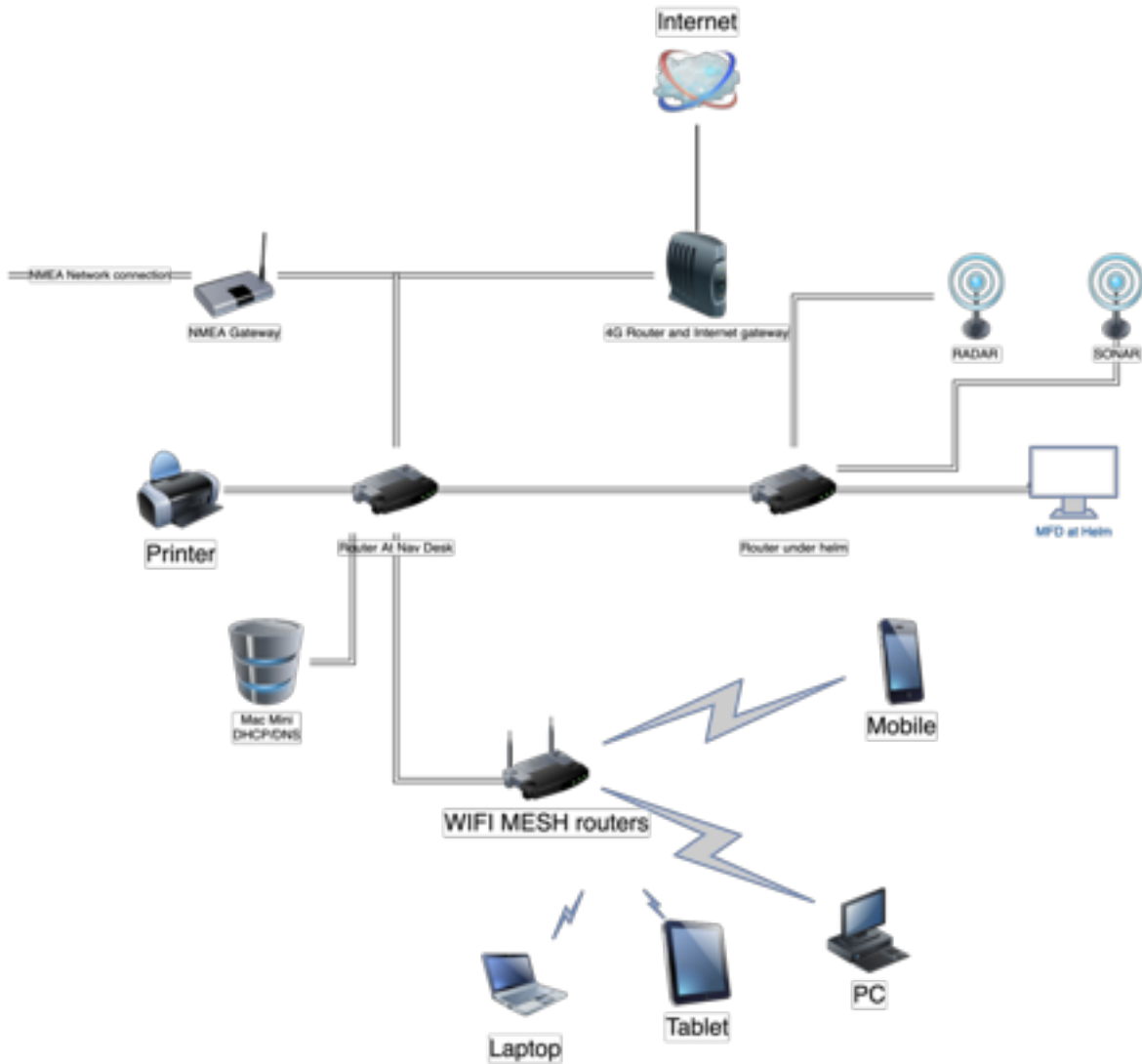
I didn't need to replace any of this or structurally change it. It was fit for purpose, but I wanted to extend that purpose and the associated benefits.

I had some goals:

- Get all the available NMEA data that was travelling around this network onto a shared ethernet network (TCP/IP like your home computer uses) and through a WI-FI network (which is simply TCP/IP over Wi-Fi).
- Add an MFD into the saloon that would have all the NMEA data available, as well as radar and sonar data so that I could navigate from inside when weather was inclement, as well as when I was on passage.
- Be able to add devices as I saw fit from practically any manufacturer, rather than being locked into a single proprietary environment or supplier.
- Be able to leverage mobile navigation software on my iPhone and iPad tablets as well as on my laptop.

So even if I wasn't going to add these immediately, I should include them on the planning design stage so that I can understand how I am adding them, where and what I need to provide now and then.

This is what the final TCP/IP network looked like.



To achieve my goals this network would also have a Wi-Fi router attached so I could connect wireless devices to the network as well as a 4G router and a NMEA Gateway all added to the basic network design.

I wanted it not only to be cost effective but also more robust than a household setup, and all run on 12v if possible.

The last part of the equation is a 4G router that would allow me to connect this network to the outside world via a mobile SIM.

This was wanted for various reasons, including remote monitoring, anchor alarm, remote switching etc, whilst also enabling a 'normal' life using Netflix and email seamlessly whilst also being connected to the boat NMEA data.

FIRST BUILD A WIRED NETWORK (ETHERNET)

The Core Network Cabling

Wi-Fi is great, but it can be unreliable if there are other things interfering with it. Speeds, although 1000's times faster than NMEA2000 (N2K) can still be slower than you want.

For a wired network you need a few services and some cables and routers.

I put two routers (industrial 12V but not marine) into the boat, one into the navigational table and another under the helm section.



I could have chosen a router that also had WI-FI on it, but I deliberately did not because I wanted to have more control and redundant support for core services, i.e., if I lost the Wi-Fi, I would still have a solid wired network. It also meant that these were simple and highly reliable 12V routers.

The one's I chose were supplied with 240V plugs that stepped down to 12V for the router, so it was very easy to wire them into the boat 12v system by just cutting off the plugs.



We probably need to talk about Routers so please have a quick look at the **The Role** of a DNS server

DNS stands for Domain Name Server and it is effectively a computer, or more accurately a network of computers that hold a phone book of data that maps a Domain Name, what is known as a Fully

Qualified Domain Name (FQDN) and is human readable, like www.SailingWaiata.com into a network IP address that computers use to talk to each other and TCP/IP knows how to route.

So a query to a DNS for www.SailingWaiata.com would return the IP address of 139.59.161.151 (The IP address of our website).

DNS servers are in a network so if one doesn't know the answer it will forward the request to another one until it either gets the answer or fails. If it fails you can't contact that service.

So to be clear, when we setup www.SailingWaiata.com we had to go to the DNS authority for our Domain Name supplier and update the "Phone book" listing (Called an A record) for the IP address for this domain and this address would then be sent out over the DNS network so it would be fast to find.

About routers below.

I joined these with some [CAT6 cable](#) and then routed everything else off these two routers: one in the nav station and one behind the helm. The picture above without the modem represents what I had, with the Cat6 cable (yellow in this picture) being run through the boat between the two routers.

Providing DHCP for the new network

I then plugged a Mac Mini into this network (I did also try this with other devices, like the Raspberry Pi which I had for the Chart Plotter and a NUC) which was going to form the DHCP and DNS services on the network.

NOTE: I used the Mac Mini for the DHCP, but on my little network I have a Rpi 4, 4G Router, B&G MFD, NAS and even my Fusion Radio that all have built in DHCP if I wanted to use one of them. I already owned the Mac Mini and wanted it on the network for other services so it was a good place to stand up DHCP.

If you wanted to use a Linux NUC:

[This guide shows](#) you how to do it on an Ubuntu server. It's very similar on all Linux variants. This is probably the easiest and cheapest (other than an RPi) option.

If you wanted to use a Windows NUC or PC:

You would first need the Server version of Windows, and this might get a little expensive. But this [guide will show you how to do this on 2016 server](#)

If you want to use a raspberry Pi:

This is a good guide [to how to do that](#). The software you install is called DNSMasq and can also allow you to setup a [DNS server](#) on the RPi so killing two birds with one stone.

If, like me, you wanted to use MacOS:

This guide shows you how to setup a [DHCP server on MacOS](#) Server or even client.

Use your Router for DHCP

Many home routers come with their own DHCP server built in and you can use this if you use a Router that has a built in DHCP server. Your WAN router that comes with your internet connection will have a DHCP server built in and by default turned on as it expects to "own" the network in your home.

Setting up a DNS server

You don't necessarily have to setup a DNS server, but you do have to setup what DNS server your computers should use.

This might sound confusing but remember that DNS is just about turning human readable FQDN's (Fully Qualified Domain Names) into IP addresses and as your boat will probably not be using FQDN's the only time you'll need to use a DNS is to get a public DNS record. So you can actually just use a public DNS like Google's DNS servers which can be found on **8.8. 8.8 or 8.8. 4.4** or you can use your public gateway IP as it will have a DNS set for it by the public connection (mobile network if you are using 4G).

For my network on the boat, I have just setup the DHCP to allocate the IP address of the network gateway as the DNS server. Anything it can't answer, which will be most things, will be forwarded to its DNS server on the 4G network for an answer.

So, this was the completed "HARDWARE" for the TCP/IP network, minus the 4G and Wi-Fi and NMEA gateway which would come later and practically, just plug in to the router.

ADDING A WI-FI NETWORK

Once you have a wired network with routers with free ports, to add Wi-Fi is simply a matter of getting a Wi-Fi access point and plugging it in. There will be some configuration but that will be minor.

I used a home Mesh Wi-Fi network that used a 240V plug adaptor for 12v, so again I could just cut off the plug and wire them into our boat's 12V system.

Because it was a MESH network, I could put one near the Nav station and plug it into the TCP/IP router there. The others would just network off this one, as MESH does. This meant that I could have three access points around the boat (one in each hull and one in the saloon). This might be complete overkill for your boat, but we use Wi-Fi extensively and have a 45' catamaran so this worked out perfectly for our needs.

The MESH setup was done via Bluetooth using their app and I could setup a separate Wi-Fi network that would "bridge" to the wired one, or just have it extend the wired one as an Access Point (AP). This would mean that the DHCP on the network would provide IP addresses for all devices including Wi-Fi and it would work just like being attached physically. This is what I did.

NOTE: the Wi-Fi network was created as a separate access into the wired network so that it would share all the services I added to the wired network and was a separate component. Beware of devices, like bridges (gateways) that provide their own Wi-Fi. You will end up with multiple Wi-Fi's that are connected. Hence, I wanted my Wi-Fi network to be "just an extension of my wired network" not something extra special.

NOTE: I also provide a Guest Wi-Fi that is separate but that will be the subject of another White Paper. It means guests get 4G data but no access to NMEA and other private network services keeping my stuff on the boat secure to me. The guest Wi-Fi was simply an option to turn 'on' in the MESH setup.

Now I could use iPad applications and iPhone applications over Wi-Fi to access the NMEA data such as iSailor or NMEARemote.

Mac Mini failed for some reason I could simply turn on DHCP on the device and the network would continue to operate.

I'm big on redundancy.

The 4G router, although designed to be the primary server on the network, providing DHCP et al, would be happy working as a simple 4G router and provided 4 physical network ports as well as redundant Wi-Fi. As you might understand having enough network ports can be a problem by the time you have everything plugged in, so four additional ones are a bonus.

I setup the 4G router, which came with a web interface to configure, with a static IP address and made that IP address the gateway address for my network.

All traffic through the network would go to all machines, because I was just using standard routers (see:**The Role** of a DNS server

DNS stands for Domain Name Server and it is effectively a computer, or more accurately a network of computers that hold a phone book of data that maps a Domain Name, what is known as a Fully Qualified Domain Name (FQDN) and is human readable, like www.SailingWaiata.com into a network IP address that computers use to talk to each other and TCP/IP knows how to route.

So a query to a DNS for www.SailingWaiata.com would return the IP address of 139.59.161.151 (The IP address of our website).

DNS servers are in a network so if one doesn't know the answer it will forward the request to another one until it either gets the answer or fails. If it fails you can't contact that service.

So to be clear, when we setup www.SailingWaiata.com we had to go to the DNS authority for our Domain Name supplier and update the "Phone book" listing (Called an A record) for the IP address for this domain and this address would then be sent out over the DNS network so it would be fast to find.

About routers), but if the network traffic was looking for something outside the network i.e. on the internet then it would go first to the gateway (4G router) and that would handle that part of the traffic.

So, I immediately had internet access.

One thing to be wary of is you need to not only make the 4G routers IP address the network gateway but also assign it as a network DNS (at least one of them). This would mean when I typed www.google.com into my browser it would query the network DNS's, the first one on the network wouldn't know, but the 4G router would forward this to the internet's DNS as part of its mobile connection and would return the correct IP address I needed to contact Google.

If you forget this step, you will find you can't reach things on the internet, because you can't resolve the names for them to IP addresses, the role of a DNS.

HOW NMEA OVER TCP/IP WORKS

NMEA is a simple data stream. Little packets of information are broadcast over the network continually by devices and systems so that it's available for consumption by any other device on the NMEA network.

These packets of information are called sentences and each sentence describes something of value like depth, location in GPS coordinates, speed etc.

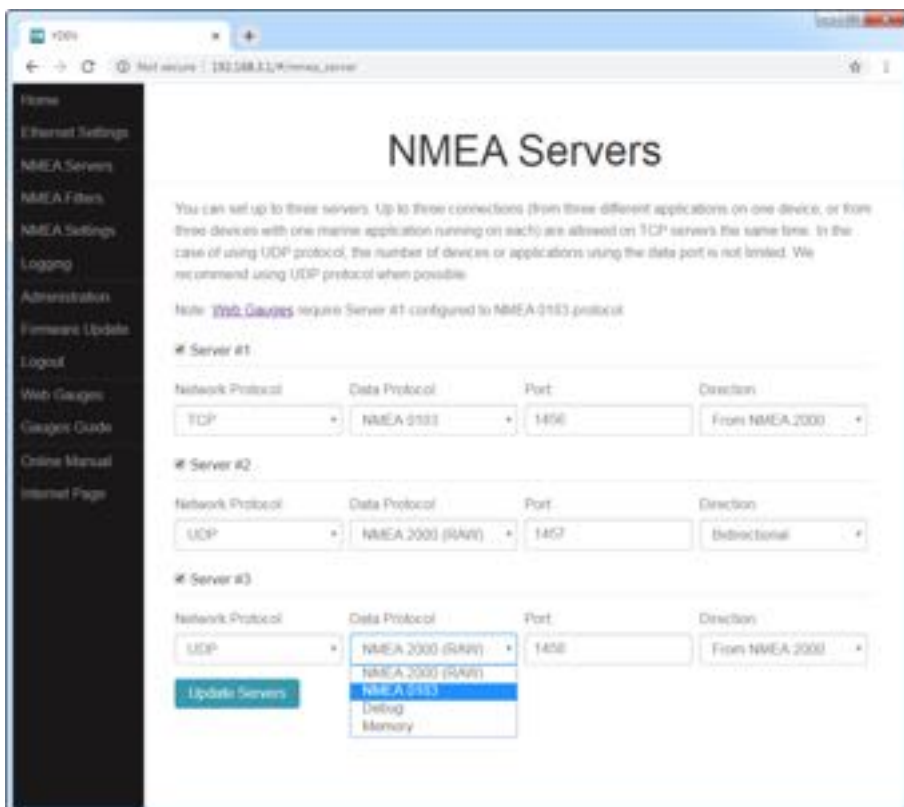
When you move this onto a TCP/IP network it is presented to applications on the TCP/IP network as a service that is streaming this data. That service has an address, like any other device and a thing called a port. To give you an idea of how this works a website is a service that presents HTML data over port 80 or 443 if you are using SSL.

If you are browsing www.sailingwaiata.com over HTTPS you would be connecting to 139.59.161.151 on port 443 and what you would be getting back is HTML code for the website to be interpreted by a browser and displayed.

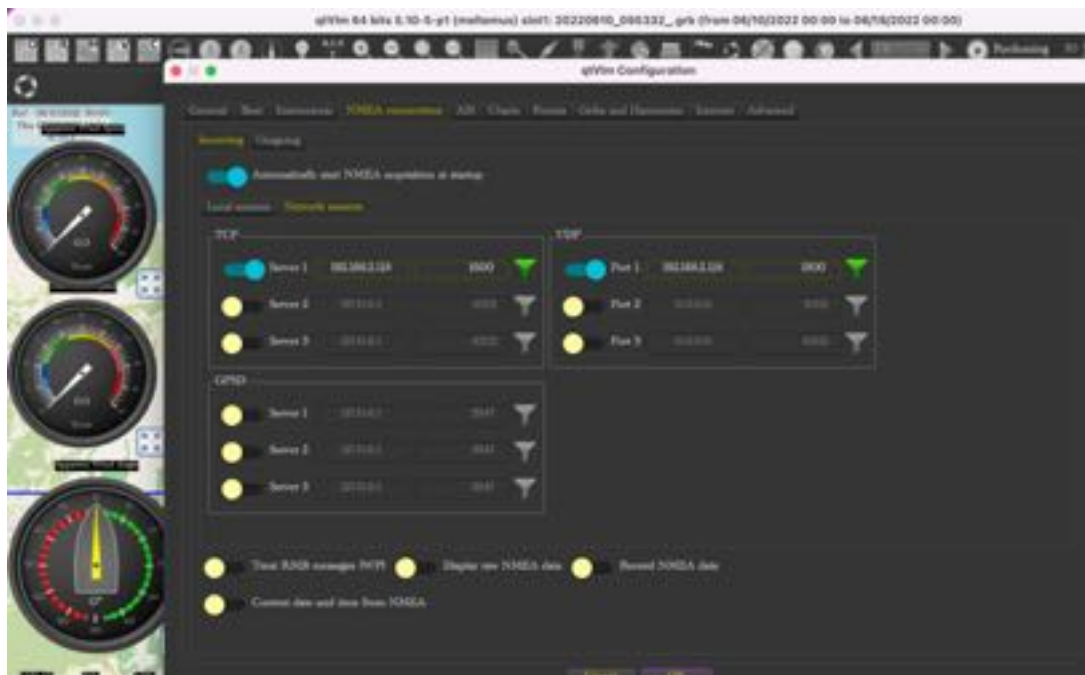
The combination of the IP address (the machine) and the port (the service on that machine) allow you to access data over what's called a protocol (a way of talking that both devices understand), so for instance, HTML for web pages. The difference between port 80 and 443 is that 443 routes the data stream through a secure encryption software and port 80 does not.

To get the NMEA data on your TCP/IP network, first you need to setup these servers using an interface on the NMEA Gateway. The interface is usually a web interface (over port 80/443) that presents you with a screen to configure things like IP address, port etc to use for the NMEA streaming.

This is what mine looks like:



Once setup you then need to tell any application you might be using where to go to get the NMEA data. For instance, on my Chart plotter (RPi) I use qtVLM for plotting and AIS et al. In its configuration page I go to NMEA Servers and set the same details as I have setup on the gateway. This is what that looks like



On NMEAremote on my iphone I set it up like this

4:53



< Back Digital Yacht (NavLink 2)

Name Digital Yacht (NavLink 2)

Enabled

State Receiving...

```
$PDGY,N2NET_INIT,ALL
```

```
0 msg/sec.
```

Validate

Rules >

NMEA

Talker ID >

CONNECTION

Protocol UDP

Port 1500

I also make sure that the IP address I assign to my gateway is a static address in my DHCP server so that it doesn't change between restarts.

ADDITIONAL THINGS TO PLUG IN

NMEA bridge

To join the two networks together, i.e., get NMEA data onto the TCP/IP network and instructions back onto the NMEA we need a device called an NMEA bridge.

Now there are lots available, but the important thing is that you get one that has the right connections to your NMEA network (See the white paper on [NMEA networks](#)) and of course to your TCP/IP network.

You can get these with Wi-Fi built in so you can get your NMEA straight onto a Wi-Fi network but this does not give you a lot of control over how you setup that network and you may end up with a Wi-Fi for NMEA and another for your boat so you can't see both Netflix and NMEA data at the same time.

I went for a simple Yacht Devices unit that took the NMEA data and put this onto the physical TCP/IP network. I would then make this available via my own Wi-Fi and make sure it was all on the single network that I could control as I liked.



Adding a Wi-Fi router

To get this onto a Wi-Fi network, I simply plugged in a Mesh Wi-Fi network (home unit that will run off 12V) so that I could have three access points around the boat (one in each hull and one in the saloon).

This was plugged into the same router network behind the Nav station.

You don't need a MESH unit and you can also use a device that does multiple things like a router and Wi-Fi for adding your Wi-Fi. I have separated them because this gives me the most control and redundancy.

NOTE: the Wi-Fi network was created as a separate access into the wired network so that it would share all the services I added to the wired network and was a separate component. Beware of devices, like bridges (gateways) that provide their own Wi-Fi. You will end up with multiple Wi-Fi's that are

connected. Hence, I wanted my Wi-Fi network to be “just an extension of my wired network” not something extra special.

NOTE: I also provide a Guest Wi-Fi that is separate but that will be the subject of another White Paper. It means guests get 4G data but no access to NMEA and other private network services.

Adding a 4G Router (4G)

Getting your network connected to the internet is simply a matter of plugging in a Modem device into your router and configuring it correctly.

This could be a 4G router, as I did, to connect your network to the Mobile network in your area. It could also be a Starlink router or another satellite Modem device.

The procedure is the same but also different. It’s the same as far as your network is concerned, this device must be connected as a Gateway on your network, somewhere that data can be routed outside your subnet.

From the devices point of view, you will need to configure it according to the supplier’s instructions to get it to connect to the network.

4G/5G routers are fairly straight forward to setup and connect and the network gateway and DNS records will be the more complicated part. But hopefully you’re understanding how easy this is now.

Radar

My B&G Radar has a data connection that although it has “special” connectors, it is just CAT 6 cable and uses TCP/IP to transmit its data to the Zeus 3 MFD at the helm.

I cut the connectors off and added normal RJ45 connectors. This then plugged directly into the router and the MFD also plugged into same router.

The last thing I needed to do was go into the settings on the **MFD and TURN OFF ITS OWN DHCP** server. Normally the MFD is the DHCP for the network, but the network only consists of the MFD, radar and perhaps sonar.

By turning it off the MFD and radar were now part of the overall network and getting their IP address information from my DHCP server.

This meant they were all on the same network and data from the Radar was travelling through the router to the MFD and available to both it and other software running on my Raspberry Pi for instance or even WI-FI devices such as my iPhone.

Sonar

I have left the sonar plugged into the MFD directly and it is not on the network. This is because I currently have no software, other than the MFD, that can interpret the Sonar data and display it.

It still works because the MFD passes through the DHCP from the network and the sonar itself gets its IP information from the network DHCP server as per everything else.

NOTE: it is very possible, even probable, that the MFD is working like a router and the data from the sonar is on the boats network. If anyone builds an opensource sonar plotter for the Raspberry Pi I will install it and see if it is already getting the info.

A more flexible Chart Plotter (MFD)

Now you might remember I didn't have a Chart Plotter in the saloon's Nav station.

To remedy this I built a Raspberry Pi MFD, which will be the subject of another white paper, and installed that into the Nav desk together with a 16" touchscreen.

Because I had all the NMEA data, radar data and other network data on the network, once the RPi was plugged into the network router it too had all the data that the main helm MFD had and could present this using several different software programs as I pleased.

This included all the below:

- Wind direction and strength as well as true and apparent
- Water temperature, depth, and boat speed through water
- Heading, GPS position, COG and track
- AIS information complete
- Radar control and data
- I suspect sonar data, but I have no software that can interpret it yet.
- Internet access via 4G gateway so access to
 - Weather reports and actuals
 - Wave and swell forecasts
 - Weather warnings and internet NAVTEXT
 - Full grib file downloads
- Battery information in detail from network attached BMS and MPPT/Inverter Solutions.
- Tank information
- Later engine information will be added via NMEA



A Raspberry Pi is a small single board computer that runs Linux and can run software just like a normal computer.

The Rpi I chose was a [Model 4 with 8G of memory and the now list price for these are £55.50](#)

MOBILE APPLICATIONS GALORE

As well as having all this data now travelling through my wired boat network, because the Wi-Fi network connected directly to this, I now had access to all this data on any mobile device that I wanted to attach to the network.

This meant that I could now run iSailor on my iPad for routing, connect NoForeignLand to my position via the boats GPS and download boat tracks to it on my laptop directly from the Rpi or the MFD.

Network attached storage (NAS)

I also added a NAS to the network, this was a simple matter of plugging it into a power source and connecting it to the network via the router and a Cat 6 cable.

Once this was completed everything on the network could now access it for storage or to retrieve data from it.

I could save routes into a folder that was on the NAS and retrieve them from the Rpi, or a mobile device iSailor for instance, or I could play a movie stored on the NAS via a player on the Mac Mini and stream this to the TV in the saloon via the Wi-Fi.

I have serious highspeed data storage on the boat now!!!

A QUICK NETWORK 101 FOR BEGINNERS.

TCP/IP networks are exactly what your home or work computer's use.

- [CAT6 cable](#) is just the network cable you might see at work (or home) that is usually blue or black
- [RJ45](#) is the plug you use to plug in the network to your computer or the router etc. that is attached to the end of the cables
- [A router](#) is just a small device that lets you join multiple devices (like computers) to the network
- [A bridge](#) is just a network device that takes traffic (information) from one network type or segment and puts it onto another network, capable of filtering out things you don't want to take across. The NMEA gateway is a bridge device for TCP/IP taking information from an NMEA network and bridging it across to the TCP/IP network as appropriate.

There is a lot to understand about TCP/IP networks, but you don't need to understand most of it to use it or even assemble a basic network.

Let's face it, you use your computer all the time at home without doing much other than plugging in the router the internet company gives you right?

To build you own network you need to understand a few things

TCP/IP (Transaction Control Protocol over Internet Protocol, which simply means a way of talking between devices) uses addresses a bit like phone numbers to talk to devices and get information back and forth.

These addresses come in two formats these days, IPv4 and IPv6, but we'll focus on IPv4 for this, which is really all you'll need to understand currently.

TCP addresses are 4 numbers separated by three dots, like 192.168.1.1. Each number is an 8-bit number in binary so can store up to the value of 255. We can use these four numbers to split networks up into separate areas, [subnets](#), so that only information that is bound for one "network" is sent to that network. We do that by specifying a network mask for an address.

A mask looks like 255.255.255.0 which would say for 192.168.1.1 we are only interested in the last digits and any information that is addressed to an address other than 192.168.1.? will be ignored and not forwarded on our network. This mask BTW, would allow for 255 devices on this network.

The next thing we need to understand is what are the Gateways on the network, i.e., if we have a message, we want to address to a device outside our network mask (Say 192.168.2.?) where would we send it; which device (Gateway) would know how to get it to the right network.

The last thing we need to know is where are our DNS, Domain Name Servers. DNS are simply computers that keep a telephone book that know how to convert a human name like www.sailingwaiata.com into a TCP/IP address like 139.59.161.151 (The IP address of our website). DNS servers don't need to know every address, they can refer up to their own DNS servers if they don't understand the address.

Now, this is the important bit

Every device on the TCP/IP network gets an address like this



IP Address 192.168.2.9

netmask 255.255.255.0

Router: 192.168.2.100

broadcast 192.168.2.255

DNS: 192.168.2.1, 192.168.2.100

The address (think phone number) of this device is 192.168.2.9 and its netmask is 255.255.255.0 so it's only interested in information sent to the network of 192.168.2.???

If you want to address a computer outside that network then the message will first be sent to the gateway computer on that network, the 192.168.2.100 (which in this case is the 4G mobile network router)

If you only have a human readable address (like www.sailingwaiata.com), then first you will send a message to 192.168.2.1 or 192.168.2.100 to ask what the real IP address is and so on. You'll get back 139.59.161.151 in this case.

The broadcast address is just an address you will send messages if you want to talk to every device on your network (192.168.2.? in this case)

Remember you don't need to send these messages, the computer does this for you, but it needs to know where to send them.... so the gateways, dns servers etc. need to be set.

The Role of a DHCP Server

We now know what a TCP/IP address is, what a router and gateway is and what a network mask is... so what is the DHCP thing that is shown in the picture above?

A network will work without a DHCP server, but every single device on the network will need to have the IP address, mask, gateway, dns etc. set manually. Which means adding devices can be quite difficult. A DHCP server automates this process for us.

DHCP stands for DYNAMIC HOST CONFIGURATION PROTOCOL, and it is simply a network service that provides all this information when a computer connects and sends a broadcast message and asks for an address to be allocated, please.

It would get back from the DHCP server an allocated IP address from the “pool” of addresses that the server maintains for its network along with the gateways, DNS servers etc.

These addresses will be given out on a “lease” that will timeout eventually and if the computer does not ask for the address to be continued it might be given out to another device. In this way these are called dynamic addresses i.e. you never know what address the computer will be at, only the DHCP knows that.

There are also static addresses, addresses that don’t change and are not allocated by the DHCP server. These are used for devices you don’t want to ever change, like the address of your gateways, or DNS servers etc.

These addresses are manually setup on those devices, not using DHCP, and are marked in the DHCP server as static addresses i.e., don’t allocate these to another computer. (NOTE: you can do this a different way and use the physical MAC (sort of hardware ID) address of the computer so that DHCP knows to allocate the same address to that computer every time, but for now let’s keep this simple).

ADDING A WIRED NETWORK MEANS ADDING A DHCP AND DNS SERVER

Adding a network means you have to add a DHCP and a DNS server to your network so that you can get it all working.

For this I used a Mac Mini server. Not for any other reason than I wanted a more powerful computer on the network for stuff like Netflix and because I had an old one, so it was zero cost to me.

But I could have used another, or the same Raspberry Pi if I had wanted to, or a PC or a NUC (Network Unit of Computing – a small PC in a box). I could have used a phone if I could have gotten a wired network connection to it. You get the idea.

The Role of a DNS server

DNS stands for Domain Name Server and it is effectively a computer, or more accurately a network of computers that hold a phone book of data that maps a Domain Name, what is known as a Fully Qualified Domain Name (FQDN) and is human readable, like www.SailingWaiata.com into a network IP address that computers use to talk to each other and TCP/IP knows how to route.

So a query to a DNS for www.SailingWaiata.com would return the IP address of 139.59.161.151 (The IP address of our website).

DNS servers are in a network so if one doesn’t know the answer it will forward the request to another one until it either gets the answer or fails. If it fails you can’t contact that service.

So to be clear, when we setup www.SailingWaiata.com we had to go to the DNS authority for our Domain Name supplier and update the “Phone book” listing (Called an A record) for the IP address for this domain and this address would then be sent out over the DNS network so it would be fast to find.

About routers

Now a quick word about routers. Routers are just boxes that allow you to plug in cables, these cables can in turn be plugged into devices or another router. Think of them as joiners.

Standard Routers

The simplest network takes a cable straight from one device to another, but then you can't connect anything else. But if you put a router in the middle you can then plug in other devices as you see fit or as many as you have ports. If you need more ports, plug in another router.

Standard routers are simple mechanical devices and usually don't have any interface or programmability built into them. They are highly reliable and low power consumption.

Now most of the readers will probably understand routers from the internet connection that their ISP provides to them. These are what are known as WAN routers.

WAN Routers

WAN or (Wide Area Network) routers have a special port that is usually labelled WAN and are designed to attach your Router to the WAN the dialup, broadband, fiberoptic etc. These WAN ports are NOT TCP/IP or at least not standard TCP/IP and usually have a Modem type device connected internally to them.

Internally the WAN port is connected to a device that understands how to connect to a WAN of that specific type, broadband, fiberoptic, dialup etc. (a [Modem device](#)). They have computing power and a UI that allows you to provide the information you need to be able to connect to that particular type of network.

Otherwise, these WAN routers work just like a normal router and the other ports are just normal TCP/IP ports, so you can use these as network routers if you have one available, just don't use the WAN port.

Some of these will have [WI-FI routers](#) BUILT IN, this is the same as connecting a WI-FI router to the router by plugging it in but of course it's all done internally. So, you sort of get three things in one box along with the software for each of them. Make these cheap and they tend to not last very long and be slow relative to specialized components. They will also consume much more power than a simple standard router.

This would be my only warning about using a WAN router, most of them are not designed to last very long and are cheaply made. Maybe less value and reliability than you want on your boat.

Switches

For this you shouldn't need to understand Switches. But just in case you have one available or get confused, you should perhaps understand what a [Network Switch](#) is.

A Network Switch is a small computer, it functions like a router, but it also can "Read" the data flowing through it and control what goes where so that all the messages don't go everywhere all the time (which is what a standard router does).

You would use a Network Switch to separate traffic between different networks and raise the performance of each network leg as well as introducing security layers on top.

Trust me if your boat network requires a Network Switch, you'll already have the knowledge to do it and for a simple boat (or house) network you won't be needing switches.

A Crash course in Network Addresses and Subnets

TCP/IP Addresses or [IP Addresses](#) cover a huge range of addressable numbers in the range of 2,147,483,647 separate addresses.

This would seem like plenty but as you have seen many are needed for special purposes like broadcast and there are now millions of computers around the world. To accommodate this certain address ranges were nominated as PRIVATE address ranges.

These private address ranges are used inside a private network and mapped outside using a thing called NAT ([network address translation](#)). Therefore, the same address range can be used by everyone as long as they are private and separate within in those private networks. NAT works by having a Public IP address (an address from the public range) on the gateway so that it can be addressed from the internet and then it maps the messages back and forth between internal and external IP addresses.

The 4G router or most other devices for connecting to the internet like Modems will use NAT to hide your internal network and map addresses into and out of your private network.

To this end you should use a private network range for your boat network.

Reserved private IPv4 network ranges ^[9]				
Name	CIDR block	Address range	Number of addresses	Classful description
24-bit block	10.0.0.0/8	10.0.0.0 – 10.255.255.255	16777216	Single Class A.
20-bit block	172.16.0.0/12	172.16.0.0 – 172.31.255.255	1048576	Contiguous range of 16 Class B blocks.
16-bit block	192.168.0.0/16	192.168.0.0 – 192.168.255.255	65536	Contiguous range of 256 Class C blocks.

For my own networks I have chosen a network address in the 192.168.0.0 range. Within this range I could have as many as 65,535 IP addresses so you get the idea it's enough.

So , here's a quick overview about Subnets

A subnet is a group of computers that all share a network address apart from the last few numbers. It's like living on the same street and all sharing the same address apart from your actual house number. You would live in what IP call a subnet.

If my network had a Network mask of 255.255.255.0 then I would have a subnet of up to 255 devices. i.e., it's only the last byte of the address that will separate all of them.

Because of the way routers work I can send a message to any device on that network just by sending a message on the network addressed to that machine, because all 255 devices on that subnet would see the message and only the correct one would bother to pick it up.

But if I sent a message to say 139.59.161.151, the IP address of www.sailingWaiata.com (you'll note it's NOT a private address range but a public one) the message would be addressed first to the gateway device/s on my subnet because they would be the only devices that would know how to send it to the machine.

In my case this would be my 4G routers and it would send the message to 139.59.161.151 via its gateway, the mobile network gateway setup by its own DHCP when it joined the mobile network.

So, when you design your network, choose a private network you want to use for it and put it into the design.

NOTE: you can get quite complicated with this. For instance I could separate my Wi-Fi and wired networks, putting them onto different subnets, I would need a separate DHCP server on my Wi-Fi network of course, but the MESH could do this for me. I would need to setup which MESH unit was the gateway (to the wired network) and I could then apply some security rules and get quite sophisticated about separating traffic between Wi-Fi and wired.

But this would just add complications to my setup without much benefit. Hence KISS. Keep it simple. It's a small boat network!!!

What you need to know about protocols

TCP/IP is a [protocol set](#). A protocol is a set of rules that allow to parties, or devices to communicate using those rules to understand what is being said.

You could say that English, French and German are different language protocols and that inside them there are subprotocols such as formal, informal etc.

[TCP](#) is a protocol for communication that runs over [IP](#). This subject can get complicated but to keep it very simple you can think of TCP as the one-to-one communications language over IP which allows you to address the messages. i.e., I can address you using your phone number (IP) and we talk German (TCP) to understand each other.

[UDP](#) is the other Protocol you need to be aware of when setting up a network and most importantly setting up things like NMEA. Unlike TCP which is a personal connection, and you need to establish a connection first, UDP is more like a broadcast, and you just need to understand how to "tune in" to the broadcast.

The big difference is that to configure NMEA (for instance) using TCP you need to have the IP address of the specific device that is supplying the data **AS WELL AS** the port number for that service. But with UDP you only need the network/Subnet that the data comes from and the Port, you don't need to know the actual IP address of the device.

Also, a BIG difference that might catch you out if you get more complicated with your network design, UDP is **NOT BROADCAST OUTSIDE THE SUBNET** but TCP can travel across an entire internet if need be.

The other big difference is that the device being addressed needs to maintain that connection for TCP so there is a limit as to how many it can cope with, think personal phone call, whereas UDP is a broadcast and everyone on the subnet can listen if they want. My own NMEA gateway device can only support 3 TCP connections at a time to the server, whereas UDP is unlimited.

UDP also does a datagram checksum, so you know if it's been corrupted during transmission or you have only received part of it, but no negotiation mechanism (because it's a one way communication)

so unlike TCP where the receiving device and sending device can ask for resends and confirmation etc. if you get an error with UDP, tough. You'll need to wait for the next transmission. This is less of a problem than you might think.

KEY FINDINGS



- A high speed wired network is becoming an essential addition to a boat
- Adding NMEA gateway and WI-FI extends your boat software options enormously.
- Redundancy is key and if done right a TCP/IP network adds to your resiliency rather than detracts from it.
- The costs of installing an Ethernet network are relatively low, especially compared to NMEA networks. A complete network with gateway, Wi-Fi and even a Chart Plotter can be assembled for less than a third the cost of a single marine MFD.
- Marine components are not entirely necessary. Good quality components are using gold plated contacts and so long as they are NOT directly exposed to salt water will be fine. They are also cost effective enough to allow spares and redundancy to be kept.
- Components for an Ethernet network are widely available around the world and easily sourced.



CONCLUSION

Adding a wired and WI-FI TCP/IP network to your boat is one of the best upgrades you can do to your boat electronics.

The costs are relatively low and open a world of diversity and savings for boat electronics.

The ability to have boat data, internet and navigational software running on a standard PC or tablet, wired or via WI-FI is a game changer.

I would highly recommend the addition of a wired and Wi-Fi network to your boat, making sure you have planned it out well and not just taken, by default, the shortest route via Wi-Fi equipped gateways, or routers that might leave you with limited control and options as far as redundancy is concerned.

The more planned route will be slightly more costly but in the long run much more resilient and flexible.

Being able to connect to one Wi-Fi network and have access to internet, NMEA, NAS and other computing resources seamlessly is a powerful place to be. Even updating software on my NMEA network using the MFD (which connects to the same network) is seamless. As opposed to having to connect to one WI-FI for NMEA devices, whilst connected not being able to use the internet and having no connection to anything else on the network without disconnecting from the NMEA and reconnecting to the main boat WI-FI.

Planning a network design is very important.