Art-Net Explained

by Wayne Howell

Artistic Licence creative director Wayne Howell delivered a seminar entitled: Artistic Licence Art-Net: The Benefits in Large Scale Installations & Applications at PLASA 09 in London. The popular session had standing room only, with candidates being turned away at the door. Subjects covered included how to maximise Art-Net’s capabilities, the integration of Art-Net into large-scale applications and a discussion on Broadcast and Unicast. The content catered for the wide variety of attendees which included specifiers, designers and end users who agreed that the discussion clarified points of use and brought people up to speed on the history of control and what Art-Net II, the latest version of Art-Net, could offer.

Art-Net is the industry’s first independent, royalty-free, internet-based control protocol, which revolutionised control capabilities within the architectural and installation markets.

Starting with a history of control, Howell’s seminar explained why he created Art-Net, its benefits and why he made it freely available to the industry . . .


Analogue

More than 30 years ago, the first remote lighting control desk used analogue multi-cores to control dimmers. This was achieved using a single wire that controlled a single channel. This method required exceedingly large cables travelling from the desks to the dimmers and was complicated by different companies using different voltages, cables and/or connectors.

The first move to solve this problem was to use analogue multiplex which used Time Division Multiplexing to transmit multiple channels through a single cable. In essence this meant chopping up the signal and relaying it down to the multiplexing box. This resulted in multiple formats such as:

• AMX192
• D54
• S20

Although analogue protocols allowed us to transmit multiple channels, they suffered from problems such as short transmission distances and noise pick up.

DMX512

The next improvement was to take the TDM concept and digitalise it. By doing this we could go to greater distances, have a higher channel count and be less susceptible to noise pick up - all of which gave much more reliable results.

Once again, there were numerous companies with proprietary protocols but the introduction of DMX512 - developed by USITT and managed by ESTA - meant the industry now had a standard with which all manufacturers could comply.

The main specifications of DMX512 are:

• 512 channels per cable
• 300m maximum distance
• 32 standard fixtures per cable
• Refresh rates up to 44 frames per second
• Digital signals so less susceptible to noise
• Free for the industry to use

DMX512 limitations and the advent of networking

DMX512 worked very well within the industry until pixel-based LED control came along, causing the channel count to go through the roof. By the time networking began to appear, consoles were already being built with 8 DMX connectors on the rear.

The industry had returned to the same problem it had encountered with analogue multi-core resulting in a need for a form of DMX multi-core. This was where the entire concept of using networking for lighting control came about, with several manufacturers developing their own solutions to this problem. To overcome the DMX limitations and an unwillingness amongst companies to share Ethernet-based protocols, we decided to design our own protocol at Artistic Licence using standard Ethernet technology. This allowed digital multiplexing of many DMX lines over a single Ethernet cable. We also decided to make it open to the industry.

The Creation of Art-Net and its release into the public domain

Artistic Licence was not the only company that felt there was a need to move a number of DMX universes over networks. We decided to publish the Art-Net protocol for everyone to make use of, thus helping to eliminate the barrier to development which the many different protocol developments had caused in the past. It was greatly appreciated within the industry: ADB was the first to adopt it into its products, and we now have over 100 manufacturers making use of Art-Net.

Art-Net has not been formally recognised as a standard by any of the trade organisations or standardisation bodies, nor are there any licencing terms. We published it so that anyone in the lighting industry can implement Art-Net within their products with no licencing costs, and invite anyone to use it if they would like to.

What does it take for manufacturers to embed Art-Net directly into a lighting fixture, for example, an in-built Net-Lynx O/P?

Increasingly less and less. Initially, a significant amount of electronics and know-how was required to include Art-Net into a lighting fixture. However, we have recently developed a single board module (and optional evaluation board) that takes care of converting Art-Net to DMX and can be built into the product with the addition of only a few external components.
So why did you choose to use Ethernet when it came to lighting control?

There are many positives to using Ethernet for lighting. Firstly, we can use an existing network protocol and all its associated equipment. Not only do protocols such as Art-Net and ETCNet sit at a higher level than proven protocols like TCP and UDP on networking, they do so without us having to worry about the details of how information gets from A to B.

From an installation point of view, modern buildings already have an Ethernet infrastructure in place and, cost-wise, IT equipment and cables have (and continue to) become cheaper.

Cat-x cable has become commonplace within buildings, is low cost and, generally speaking, is more acceptable to contractors who do not understand (or like) XLRs cable.

All modern Ethernet wiring is in star format - point to point - allowing us to configure and re-configure easily and providing greater reliability. For example, if you disconnect a connector, you know you are disconnecting only one end from the network whereas with DMX you could be disconnecting anything from 1 to 32 devices!

A comparison between DMX connections and Ethernet connections.

Ethernet gives us higher bandwidth (10BaseT allows for 40 times more data than DMX cable) and can be transmitted over a wide variety of media including WiFi, laser and fibre optic.

By using Ethernet, we can take advantage of ongoing developments within the IT industry and benefit from the existing IT market technology, which is pushed by a high research and development budget than our technology, which is pushed by a high and benefit from the existing IT market ongoing developments within the IT industry.

What are the disadvantages of Ethernet?

Unfortunately, Ethernet does have some downsides.

It can run only up to 100m, whilst its star network configuration means a cable must be used for each device rather than looping through as we do with DMX. Ethernet is also less forgiving and a much higher level of knowledge is frequently required from the people dealing with it and during fault finding.

What are the benefits of Art-Net?

Conceptually, Art-Net remains a multi-core carrying multiple DMX lines: a DMX universe is added to the network and tagged with an address which is notionally one of 256 universes. However, the beauty of Art-Net lies in its ability to remotely reconfigure the address and therefore completely re-direct data traffic.

Art-Net supports RDM (Remote Device Management) which is a new protocol developed by ESTA. DMX sends data over pin 2 and 3 of the DMX cable and RDM reverses the direction so that it can receive data from the RDM-enabled DMX fixtures. DMX therefore becomes bi-directional and allows us not only to program start addresses remotely but, more importantly, means information from the fixtures, such as temperature and lamp life, can be fed back to the controller. This gives precise control over fixtures with the result that DMX equipment and techniques can now be employed within the architectural lighting industry.

In addition, Art-Net can be used with other resources including DMX-Workshop and Net-View (available from the Artistic Licence website) and Wireshark, a free to use Ethernet packet sniffer. An Art-Net SDK is also available from the Artistic Licence website.

So does this mean DMX is dead?

No! DMX is still a valuable part of the network system. DMX is very robust and, unlike Art-Net, can easily connect to multiple fixtures.

Whilst Art-Net is used to transport multiple universes from the controller to the system nodes via the Ethernet system, DMX cable is used to cover the peripheral distances and connect to the actual fixtures.

So how does Art-Net work?

The key packet in Art-Net is called Art-DMX and is used to transfer the DMX data over the Ethernet network. It can be generated within the actual controller or can be converted from a DMX source.

The Art-DMX packet contains three main pieces of information.

- 512 channels of DMX values
- 5 control fields including the universe number (to distinguish from others on the network)
- The order number. As some packets may be delayed it is important to include the order number so the receiver knows whether to ignore a packet that has arrived out of sequence

Broadcast, Unicast & Multicast

There are three ways in which you can send this data:

Broadcast has one transmitter which sends data to absolutely everything on the network; Unicast is more of a one-to-one relationship where data is transmitted to a specific IP address; Multicast is a one-to-many relationship.

For example, if you had 20 devices that all wanted to consume the same data, you could use Broadcasting but that would mean those outside the group would be seeing that data as well. You could also use Unicasting, but you will be using 20 times as much data as you really need to. Alternatively, you can use Multicasting which means you send data only once but you are sending it to the addresses of the subscribed devices.

When we first designed Art-Net, we used Broadcast to ensure it was easy for the end-user to operate: it just needed to be plugged in and it would receive all of the data that was transmitted.

How has Art-Net developed with the times?

Today’s channel-hungry fixtures mean the use of Broadcasting has become a problem as it simply burns too much bandwidth. We therefore developed Art-Net II to make use of more intelligent systems within the network. We had a choice of Multicast or Unicast and, after careful consideration, settled on Unicast.

The benefit of this method is that people can choose what level of sophistication they want to use. If Multicast was used the cost of implementation within controllers would have become prohibitive, as would the intelligence needed to manage grouping and subscribers.

How does Art-Net II differ from Art-Net I?

Art-Net II essentially starts with the Broadcasting of data - the console always begins with Broadcast and hence is 100% backwards compatible - but it then uses a simple packet mechanism on the network to find out what universe the responders want to use.
There is a great deal of confusion about the terminology regarding Ethernet. The terms Ethernet, Fast Ethernet and Gigabit all relate to the speed of data transfer. Ethernet operates at 10Mbps, Fast Ethernet at 100 Mbps and Gigabit at 1000Mbps.

There is further confusion regarding media types, i.e. the physical entity used to carry the data, be it copper or fibre. From a copper point of view we use Cat numbers to define cable types, which originated in telephone systems (Cat-1 through to Cat-4). Networking began with Cat-5 cable, which was suitable for speeds up to 100Mbps. Other types of cables include Cat-5e, Cat-6 and Cat-7, with most building installations using either Cat-6 or Cat-7 cable to ensure they are future-proofed.

**Ethernet Physical Layer**

This refers to the network electrical connection, the way in which the signal modifies and the speed at which it runs.

For example, a 10BaseT connection can be broken down as follows:

- **10** = a multiplier for mega bit per second.
- **Base** = base band transmission (only one signal on physical wire) - as opposed to broadband which has multiple signals modulated on one wire.
- **T** = Twisted Pair.

The most popular physical layers currently in use can be summarised as follows:

- **10BaseT** has a maximum cable distance of 100m. Most of the DMX Ethernet style converters in the industry right now have 10BaseT or higher as their base level protocol.
- **100BaseT** is 10 times faster than 10BaseT and can send data at 100Mbps. While you cannot make a direct comparison between DMX data rates and Ethernet bandwidth, you can make a hand waving comparison that says 10BaseT is comparable to 40 universes, so 100BaseT approximates to 400 universes.
- **100BaseFx** uses fibre optic cable, has a speed of 1000Mbps and is widely used as the backbone of the Ethernet distribution system for the installation of lighting control.
- **1000BaseT**, sometimes referred to as Gigabit, is now commonly seen and uses Cat6 cable to achieve speeds of up to 1000Mbps. Its primary use is for video streaming applications and console-to-console communication.

A Hub is a particularly simple device, not dissimilar to a basic DMX splitter, which electrically cleans up the signal and retransmits it, with all data received transmitted on all the ports. These have largely been superseded by Switches.

**Ethernet: The Connector**

Some RJ45 connectors are designed specifically for rigid cable and some for stranded but they appear very similar. Connectors can be screened, wire type or Cat rated but if you use the wrong connector you may find it coming off after just a couple of months! It is worth noting that industrial weight connectors are manufactured by Neutrik and waterproof (IP-rated) ones by Woodhouse.

**Ethernet: Wiring Schemes**

In an RJ45 connector there are 8 cores with signals travelling on a twisted pair thus effectively providing 4 circuits. Some protocols use only 4 wires and some use all 8 wires.

This is important to know as a rapidly developing technology is the ability to have power over Ethernet (PoE). There are 2 ways to have power down the cable. If you are using one of the simpler protocols with 4 wires you can use the remaining 4 for power.

If you are using protocols which use 8 wires, more sophisticated modulation techniques have to be used so that the data signal sits effectively on top of the power. Thankfully, distribution products are looking after that for us!

**Ethernet: Data Distribution**

With networks of up to 100m of cable we must use electronics to redistribute data and there are two types of box we can use; one is called a Hub and the other is called a Switch.

A Switch is more intelligent than a Hub and does more than just transmitting all data in its entirety. It analyses the data, buffers and retransmits it. A Switch will attempt to work out what is connected to the end of the cable, and send only the data that has been sent to that device. This makes it useful for controlling bandwidth and reduces the volume of traffic over a network. It does however make fault finding somewhat harder.

So Hubs are still useful for fault finding purposes (remember you can only have 4 of them in one line) whilst on larger a network, a Switch should be used for bandwidth management.
Finsbury Avenue Square, Broadgate Estates

This installation was undertaken several years ago in London and involved approximately 600 colour-changing LED fixtures installed in the ground. Artistic Licence was commissioned to design the technology implementation, from fixtures through to control systems, and identify how programming and ongoing maintenance would work. This was achieved using Art-Net I and RDM draft version 1.0, the latter of which was still public review.

The installation was the first RDM (Draft) installation worldwide and also the first where we transferred RDM using Art-Net. The system still used DMX which was transferred data from the control room to the fixtures whilst Art-Net was used from the Colour-Tramp controller to the main control racks. Consideration was given to using Art-Net throughout the entire system but we felt this would over complicate the wiring of the in-ground fixtures. We also wanted to keep the power circuits and DMX circuits identical to each other to eliminate possible earth loop difficulties. There was still a great deal of DMX cable leaving the control room but it was seven times less cable than if we had used Ethernet direct to each fixture!

Sensors were used for measuring line voltage, temperature and water ingress; additional benefits of using RDM were being able to set the start address remotely, upload firmware and to interrogate the ‘lamp-on’ counters. All this information was sent from the fixtures to the Art-Net nodes using the RDM protocol and Art-Net relayed it back to Colour-Tramp so the system could record the status of the fixtures.

For example, we might have a lighting console connected to the network with one box that wishes to output DMX universe 200. The console sends an ArtPoll packet, a mechanism used to find what universe the responders are consuming. An ArtPollReply is returned by the nodes, such as an Art-Net to DMX converter, to report their status. The responders would say, ‘I am consuming universe 200’. At that point an Art-Net II console can switch from Broadcasting to Unicasting for that specific device, and send the Art-DMX packet directly to that node. This gives us a massive bandwidth saving, which is essential when operating in excess of 40 universes.

If the console receives responses from 5-6 responders requesting DMX universe 200, rather than Unicasting all of them, it would drop back to Broadcasting which is more efficient from a network bandwidth point of view. All other functions of Art-Net II are as for Art-Net I and, of course, Art-Net II is RDM compatible - so benefitting from full diagnostic feedback from all RDM-enabled devices - and fully compatible with Art-Net I.

Pan Peninsula, Ballymore Properties

Located in the Docklands of London, the towers of the landmark Pan Peninsula residential building have large LED lighting arrays forming asymmetrical intersecting patterns at their very top. We were asked to develop the lighting control and networking and also to program the opening night show. The latter involved wireless remote control from a rooftop approximately 300m away which had to be coordinated with the main presentation. The high channel count and distance involved meant using DMX was not possible. To add an extra little challenge there was a large amount of water between our control position and the Pan Peninsula building so we brought in some Ethernet radio products.

The Ethernet radio was very reliable but the quantity of time needed to synchronise itself when powered up was between instant and 400ms. The delay of the initial synchronisation existed as an insertion delay for the data travelling between two buildings, which was a problem considering the show had to run in sync with the live orchestra! We experimented with products from three different manufacturers and at last found one which would start up reliably.

And Finally…

Is there a relationship between ACN and Art-Net?

There is no relationship between the two protocols.

ACN is a very heavyweight protocol, requiring a significant level of processing power compared to a streaming protocol like Art-Net, which is one of the reasons ESTA started a research program to generate a standard streaming protocol which is compatible with ACN. The generic name of this new ‘standard protocol’ is ACN Lite and there are two variations:

1.31 - This program generates a protocol to move standard DMX lighting packets over the network. Data is streamed in a way that is compatible with full blown ACN.

1.33 - This program adds RDM to the protocol above. For up to date information on the progress of this program, please contact ESTA.

Is there a forum where I can find out more about Art-Net and keep informed as to its developments?

Yes. After feedback from customers and manufacturers we are creating www.Art-Net.org.uk which is a resource for everyone that uses Art-Net. The site is sponsored by Artistic Licence but is for the use of the industry as a whole. It will be online by summer 2010.

If you want to know more about Artistic Licence Art-Net, a PowerPoint presentation, a PDF download and a transcript of Wayne Howell’s PLASA09 seminar can all be downloaded from the Artistic Licence website www.ArtisticLicence.com.