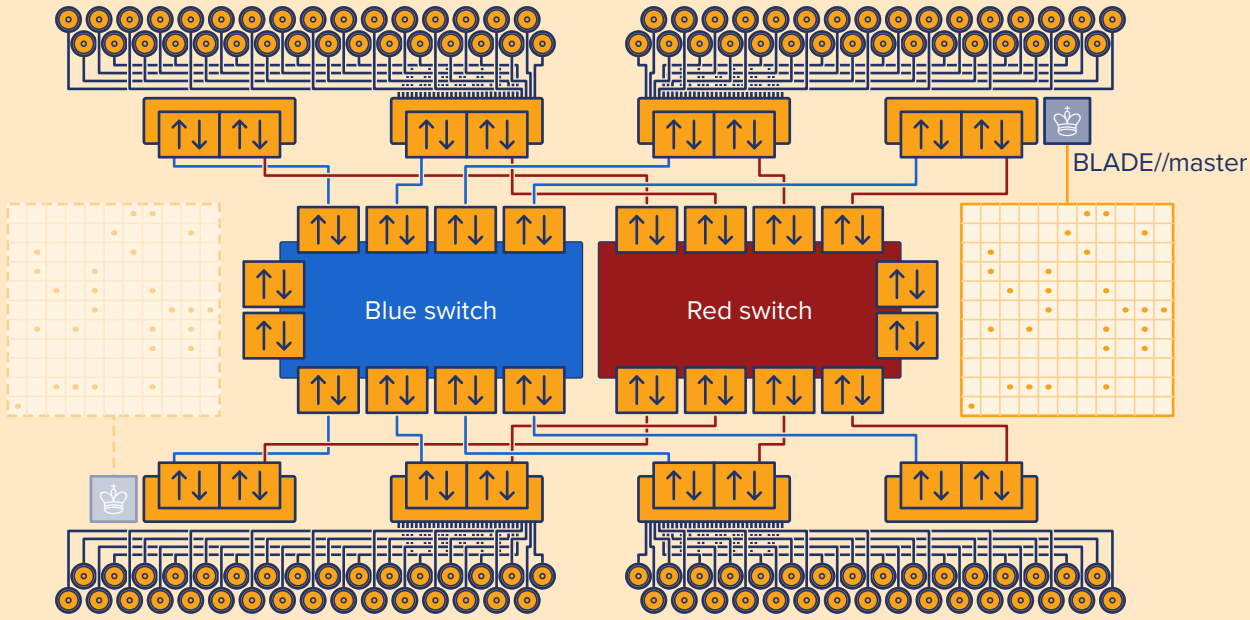
IP-READY BASEBAND ROUTING

Those in the market for video routers may have come across the theory that IP-based systems cannot replace a tried and tested monolithic SDI system.
Arguments against IP typically range from the idea that IP-based systems are too difficult to control or monitor, to unreliability in delivery of media, or the notion that IP systems cannot be built to a sufficiently large scale. In our experience, this is far from the case.
Although conventional SDI routers may currently remain favourable in price, IP systems really start to offer benefits through significantly greater functionality and scalability. This document provides an overview of how to build a reliable, easy to control, future-proof and large enough SDI router using standard Ethernet switches and BLADE//runner programmable AT300 acceleration cards ('PAC's), hopefully dispelling the aforementioned fears of an IP system.

ferent hardware configurations can be assembled, some examples of which are provided below along with their hardware and space requirements (where *100G*, *400G* indicate 100/400G Ethernet switches, *disc.*, *red.* indicate discrete or fully-redundant signal transmission, and space is measured in 19" rack units).

	Hardware	Space
128^2/UHD/disc.	8×AT300+1×100G	4 RU
128^2/6G/red.	8×AT300+2×100G	5 RU
128^2/UHD/red.	16×AT300+2×100G	8 RU
384^2/UHD/disc.	24×AT300+1×400G	10 RU
512^2/UHD/disc.	32×AT300+1×400G	13 RU
512^2/6G/red.	32×AT300+2×100G	14 RU
1024^2/UHD/disc.	64×AT300+1×400G	25 RU
1024^2/UHD/red.	128×AT300+2×400G	50 RU
2048^2/3G/red.	128×AT300+2×400G	50 RU



In a fully redundant routing setup, every baseband signal is converted into two independent packet streams that are routed over independent switches, and reassembled into a single baseband signal by 2022-7-capable stream receivers. To the outside world, the entire system is represented as a single large crosspoint matrix using the BLADE//master software component, with one or several backup instances held in reserve in case of hardware failure.

SCALE AND SETUP

Every AT300 comes with 2×100G Ethernet ports, and can be equipped with one of several hot-swappable SDI/MADI I/O modules, with up to 16 inputs and 16 outputs per module in the highest-density variant. The number of video signals that can be processed with a given number of PACs is limited by network bandwidth for UHD signals (8 in + 8 out per 100G port if every signal is transmitted redundantly, or 16 in + 16 out per PAC if not), and by BNC availability for sub-UHD signals (16 in + 16 out per PAC). Using midrange 32x100G or 32x400G Ethernet switches, a wide range of different hardware configurations can be assembled, some examples of which are provided below along with their hardware and space requirements (where *100G*, *400G* indicate 100/400G Ethernet switches, *disc.*, *red.* indicate discrete or fully-redundant signal transmission, and space is measured in 19" rack units).

The system is fully non-blocking, as switches of this size are typically built on single monolithic routing chips. For simplicity and uniformity of control, every signal is sent over the network, even if its only BNC ingress and egress interface reside on the same card[1].

COMPLEXITY

While it should be said that BLADE//runner comes with an open, fully-featured native API that allows the user to automate and customize the system to their hearts' content, such effort is rarely needed or even wanted. For the vast majority of use cases, BLADE//runner sys-

[1] this part may raise some eyebrows, as switches generally refuse to send back Multicast traffic to the same interface it was coming from, but it turns out this is actually easy to do by having the PACs ingress and egress data with different VLAN tags, a detail that is handled by our precanned setup and otherwise invisible to the user

tems can be configured graphically, and interactively, through “BLADE//planner”, and controlled via a free software translator (“BLADE//master”) between our native programming interface and the established Ember+ protocol. Beyond simple parameter control, this translator is able to abstract away the entirety of inputs and outputs offered by a set of BLADE//runner PACs as a single large crosspoint matrix, offering fast and reliable switching (using clean switching for video and quiet switching for audio) as well as a number of additional features such as automatic per-signal delay insertion and gain control. BLADE//master can be installed on as many computers as the customer wishes, or it may reside on the PACs themselves. No state is held by BLADE//master that cannot be re-obtained from the PACs it controls, such that if one BLADE//master instance should fail due to a hardware outage, an external controller can simply switch to another instance while leaving the remainder of its configuration unchanged.

RELIABILITY

The use of IP technology has become commonplace in broadcast, and IP-based tools have matured to a point where the risk of running into implementation bugs or hardware instability is no better or worse for IP devices than for their baseband counterparts.
In our experience, the one remaining major difficulty in setting up reliable IP-based workflows lies in integrating them with existing broadcast controllers that may be firmly entrenched within customers' production facilities and drive all their baseband gear smoothly and efficiently, yet have no concept of IP-specific issues such as bandwidth constraints, or the ordering requirements that may be essential to the glitch-free functioning of a distributed signal processing pipeline. To bridge this divide, we made sure that the matrix interface offered by BLADE//master *does* conform to the implicit assumptions of an SDI-minded controller, keeping all underlying complexity neatly tucked away. This permits the customer to not only integrate BLADE//runner seamlessly into an existing production environment, but to enjoy the substantial reliability *benefits* that an IP-based setup enjoys over an SDI-based alternative: In a fully redundant setup, every signal takes two independent paths through independent cables and independent switches. A switch may fail or be hot-swapped during operation without any effect on signal integrity. Apart from full failure, the system will smoothly handle signal degradation, as every receiver continuously receives both of its redundant streams and merges them based on packet sequence numbers. Should dirty optics or faulty cabling cause transmission errors that error correction is unable to compensate, Ethernet check-summing will discard the affected packets, causing their healthy counterparts from the other stream to take precedence; leaving the resulting signal unharmed.
Every PAC can be hot-swapped and its predecessor's state can be restored within approximately 2 to 3 minutes. Likewise, reboots after power failure are reasonably fast; a PAC that loses power will automatically reboot as soon as power is restored, becoming operational about 30 seconds later, and fully operational 50 to 90 seconds later when IGMP recovery and PTP recalibration are taken into account.

FLEXIBILITY

A router based on BLADE//runner PACs offers a considerable amount of signal processing features that can be flexibly licensed and activated as the need arises. A redundant 128-card 2 048 × 2 048 UHD router, for example, offers nonblocking, single-channel audio shuffling and routing for up to 786 432 channels, audio mixing for up to 524 288 channels, 1 536 HDR/SDR converters with tetrahedral interpolation, up to 3 072 color correctors, 147 456 channels of audio sample rate conversion, 640 UHD Dirac video compressors, 1 536 UHD video mixers with keying capabilities, 128 GB of audio delay memory (which, in single-channel terms, corresponds to 227 hours of 48kHz, 24-bit audio) and 1 024 GB of video delay memory (for a total of 1 060 seconds of UHD delay). Every blade can furthermore be used as a PTP master for third-party devices (optionally locking to GPS and/or providing tri-level/wordclock sync if a MasterSystemClock I/O module is inserted), or rebooted into the JPEG-XS application for 8 UHD encoders or decoders per blade, or into the audio processing application for up to (per blade) 1 024 compressor engines (for a total of 4 096 compressor channels), 4 096 RMS loudness meters, 558 True Peak meters, as well as 8 192 biquad filters and 8 192 faders that can be flexibly partitioned into audio mixers (stereo/downmix/n-minus-1) and mid/side processing effects.
It also bears mentioning that BLADE//runner PACs do not implement a fixed-function pipeline, but have all their signal processing elements connect to internal video and audio crossbars. Accordingly, no function is bound to SDI inputs or outputs, allowing the user to smoothly and incrementally migrate the system towards a fully IP-based workflow later, with no reduction in switching or processing capacity, and no sunk costs except for the comparatively cheap I/O modules.