VOEvent: Where We Are; Where We're Going

John Swinbank
University of Amsterdam, Netherlands

1 Introduction

This meeting, *Hot-wiring the Transient Universe III*, is explicitly focused on the opportunities presented by "rapid, coordinated, multi-wavelength follow-up observations" of transient events. As amply demonstrated by the other manuscripts in this volume, the potential benefits are manifold. However, achieving the best possible scientific return requires addressing a range of technical challenges in terms of identifying transients, classifying them, disseminating news to the community and coordinating follow-up. Here we discuss VOEvent [4], which provides the basis of a solution to many of these issues.

There already exist mechanisms by which astronomers may rapidly distribute notifications of ongoing and recent events[1]. However, the next generation of large-scale survey projects by telescopes such as Gaia, LSST and SKA promise a step change in transient detection rates: we are moving from an era of a few transient alerts per day to, perhaps, tens of millions. This presents a massive scalability challenge. New ways of working are required: it is obviously impractical for even large numbers of astronomers to write, read and understand millions of event descriptions, let alone to do so quickly enough to enable scientifically relevant follow-up observations.

VOEvent defines a standardized, machine-readable way of representing information about a transient event. VOEvent is flexible enough to usefully describe a wide variety of phenomena, while being appropriate for automatic generation, transmission and parsing. In this way, the human astronomer can ultimately be removed from the loop: transient detection software generates VOEvents describing the events observed, which are rapidly shipped to interested follow-up facilities worldwide, where intelligent systems can decide whether further observations are appropriate. VOEvent then provides a mechanism for those follow-up facilities to notify the community about their observations.

[1] Of particular note are *The Astronomer's Telegram*, `http://www.astronomerstelegram.org/`, and the NASA *Gamma-ray Coordinates Network*, `http://gcn.gsfc.nasa.gov/`: both have long and distinguished track records of enabling transient astronomy.

VOEvent is developed by the Time Domain Interest Group[2] (TDIG) of the International Virtual Observatory Alliance[3] (IVOA). This manuscript gives an overview of the VOEvent system, and summarizes the relevant ongoing and future work being undertaken. The TDIG actively solicits community participation in these activities: please do not hesitate to get involved and make your requirements known.

2 Structure and content of VOEvents

VOEvent defines an XML schema which describes how transient events may be described in a structured way. The VOEvent schema builds upon other IVOA standards. Each VOEvent document (or "packet") describes a particular alert. Specifically, it may contain information on each of the following:

- The author; that is, the entity responsible for the contents of the packet.
- The event observed. A flexible notation is used to allow for a wide range of observations to be accurately represented.
- Where and when the observations were made.
- Instrument specific information about how the data was collected.
- The scientific assessment of the event. This provides scope for the author to describe why they believe follow-up observations are merited.
- Citations to other events. These may be used to both provide supplementary information—such as the results of follow-up observations—or to supersede or retract previous events.

All of the above information is presented in such a way that it is conveniently machine-parseable. In addition, it is possible to append human-readable textual descriptions to each section of the event, and to provide references to arbitrary URIs for further details or clarification.

We emphasize that the VOEvent packet describes a transient celestial event: it does not describe or request (other than by implication) a particular follow-up action. It is up to the recipient to determine whether any action is appropriate based on their capabilities and interests.

The specification deliberately leaves higher-level functionality which may be layered on top of VOEvent undefined (beyond some references to particular roles that entities interacting with VOEvents may perform).

[2] http://www.voevent.org/
[3] http://www.ivoa.net/

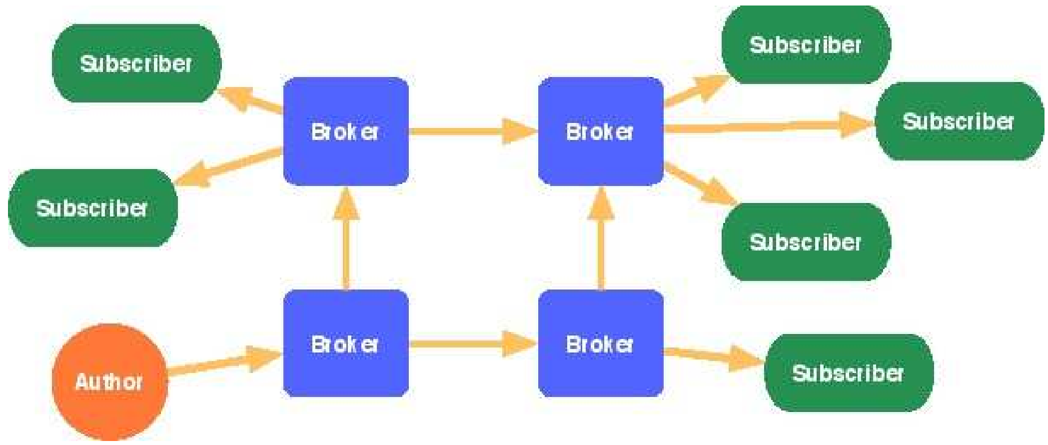

Figure 1: A schematic overview of the entities within a VTP network. The path of a VOEvent packet traversing the network is indicated by the arrows.

3 VOEvent transport

The VOEvent specification deliberately does not mandate a particular method of shipping events from their origin to interested recipients: rather, the end user is encouraged to choose a method well suited to their requirements. With time, though, it has come to be recognized that providing some baseline specification would be of significant benefit. This both provides a natural starting point for new users, and enables the construction of community wide infrastructure [6].

A basic design for a TCP-based protocol for distributing VOEvents was produced as an IVOA Note some years ago: this is the "VOEvent Transport Protocol", or VTP [1]. As a Note, this protocol has not undergone the formal IVOA standardization process; rather, it simply represents the opinions of the authors. However, the protocol has the merits of simplicity, usefulness and ease of implementation. As such, there is now an ongoing effort to update, clarify and formalize the document, so that it can move towards full standardization over the coming months.

An overview of VTP is shown in Fig. 1. In brief, the system defines three independent roles on the network: that of "author", "broker" and "subscriber". The subscriber is the end user or facility which wants to receive a stream of VOEvents. They open a connection to a broker, which acts as a distribution hub. This connection is kept open continuously. The author is the individual or facility which writes VOEvents. When they have a packet to distribute, they connect to the broker and upload it; the broker then redistributes it to all connected subscribers.

One broker may subscribe to another. When the upstream broker receives an event, it is distributed to the downstream broker (along with the other subscribers), which, in turn, passes it along to its own subscribers. In this way, the protocol enables the construction of extended networks of mutually-interconnected brokers. An author publishes to one broker, and the event is distributed to all subscribers across the network. Such a network is robust: a faulty broker can only disrupt traffic involving local authors and subscribers, rather than causing problems across the whole network.

VTP makes it convenient to build "added value" services atop the basic infrastructure as described. For example, a broker might perform server-side filtering on behalf of clients, only forwarding to them events which match criteria they have specified. Alternatively, a node on the network can record all the events it receives, making them available to clients via, for example, a Web-based interface. SkyAlert[4] provides an excellent example of the possibilities.

Open-source software is available which can perform all of the roles within the VTP network[5], and events from a number of sources are regularly being distributed. This infrastructure has already been used for published science [5], and it is hoped that this usage will grow as VTP heads towards standardization.

4 Future developments

The existing specification makes science with VOEvent possible today. However, the TDIG continues to evolve and enhance both the VOEvent definition itself and the surrounding infrastructure.

4.1 IVOA registry extension

The Registry acts as a directory of IVOA services available to the end user, be that user human or machine. A supplement to the existing registry specification is currently under development which will enable the registry to be used to describe facilities relevant to the publication, discovery and use of VOEvents: this is the "VOEventRegExt". This will be intentionally generic: not limited to describing only the simple distribution model described in §3 above but rather able to represent a wide range of event handling services.

The VOEventRegExt standard is currently at an advanced draft stage; it is anticipated that it will move towards standardization over the coming months.

[4] `http://www.skyalert.org/`

[5] *Comet*, `http://comet.transientskp.org/`, provides a Python-based implementation, while the *Dakota VOEvent Tools*, `http://voevent.dc3.com/`, are written in C#.

4.2 Security

The term "security" when applied to VOEvent infrastructure is, perhaps, overloaded. It can refer either to *secrecy*—the idea that certain events should be available only to authorized recipients—or to *integrity*—a guarantee that a particular packet was genuinely produced by its claimed author. Within the context of the current document, we discuss only the latter: the former can generally be addressed by specialist transport mechanisms between authorized parties.

Mechanisms for ensuring the integrity of a particular event can take one of two forms: either the event is exchanged over an authenticated channel or a cryptographic signature is applied to the event itself. The former method is not a good match to the distributed nature of the network described in §3. Discussion has therefore focused on the latter.

Two proposals have been made to introduce cryptographic signatures to VOEvent [2, 3]. Both rely on standard public key cryptography algorithms, wherein the author signs the event packet in such a way that the recipient can verify their identity. To date, neither of the proposed systems has gained widespread acceptance. Broadly speaking, there are two reasons for this. One is that existing event networks are low traffic and, perhaps, low prestige: there is little motivation to compromise them. Secondly, the technical considerations are still under debate. In particular, the relationship between the set of bits which constitute a given VOEvent packet and the information contained within is not trivial. It is possible, and may in some circumstances be desirable, to mutate the structure of an event while leaving its signature intact, a process which is complex, and, under some proposed systems, impossible.

The first reason will become less relevant with time: as major facilities start publishing VOEvents, they will need to protect their reputation against forgeries, and as automatic response becomes increasingly commonplace, the potential consequences of false events become ever greater. For this reason, although there is no clear standard to adopt yet, it is anticipated that security concerns will be the focus of much of the effort around VOEvent in the future.

4.3 Bulk transportation and event containers

The transport protocol described in §3 is intentionally minimalist: it provides a basic level of functionality without attempting to address every possible use case. In particular, it might not be appropriate for transporting the many millions of events which are forecast by next-generation projects. Further, the basic VOEvent standard provides no capability for including supporting information such as cut-out images.

To address these use cases, a proposal has been made for a means of bundling a number of events, together with associated files, into a single package for convenient transmission. This concept, tentatively referred to as "VOEventContainer", will be the topic of future work within the TDIG.

4.4 Alternative serialization

The representation of events as XML documents builds on widely accepted standards and makes it possible to process them with a variety of off-the-shelf tools. However, XML is verbose and can be awkward to work with. Furthermore, per §4.2, the very flexibility offered by XML makes cryptographically signing events complex. Perhaps unsurprisingly, the request for an alternative representation of VOEvent is often repeated. This would involve defining a format which contains the same information as the current standard, but which avoids the disadvantages of XML. JSON[6] is regularly cited in this context.

The TDIG is alert to the call for an alternative event representation, and welcomes proposals. However, no concrete development is currently underway in this area.

5 Conclusion

VOEvent provides a crucial piece of the infrastructure required to effectively respond to transients. It is already a mature and proven technology, and has played a key role in published science. It is anticipated that its importance will grow with the increasing data volume and consequent automation associated with current and future transient searches. The TDIG will continue to develop VOEvent to meet the challenges of the next generation: we invite the community to actively participate in this effort.

[6] http://www.json.org/

References

[1] A. Allan and R.B. Denny, *VOEvent Transport Protocol, Version 2.1*, IVOA Note, 5 August 2009.
[2] S.L. Allen, Astron. Nachr. 329, 298–300, 2008.
[3] R.B. Denny, *A Proposal for Digital Signatures in VOEvent Messages, Version 1.10*, IVOA Note, 14 May 2008.
[4] R. Seaman et al., *Sky Event Reporting Metadata, Version 2.0*, IVOA Recommendation, 11 July 2011.
[5] T. Staley et al., MNRAS 428, 3114–3120, 2013.
[6] R.D. Williams et al., Proc. SPIE 8448, id. 84480R, 2012.