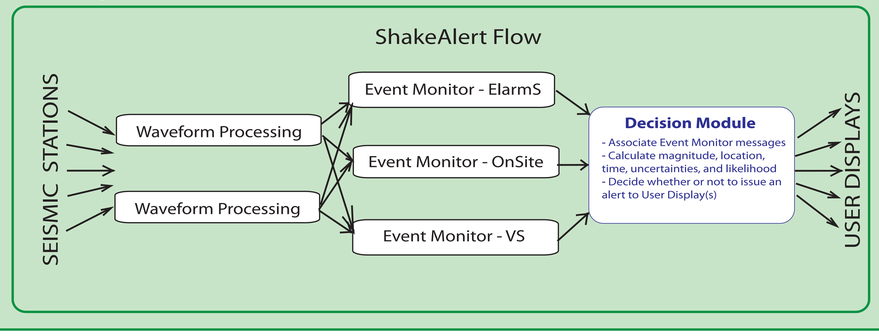
CISN ShakeAlert: The Decision Module for Earthquake Alerts

Douglas S. Neuhauser1, Oleg Khainovski1, Richard M. Allen1, Maren Bose2, Kalpesh Solanki2, Georgia B Cua3, Thomas H. Heaton2

1. Berkeley Seismological Lboratory, UC Berkeley, Berkeley, CA, United States
2. Seismological Laboratory, Caltech, Padsadena, CA United States
3. ETH Zurich, Zurich, Switzerland

INTRODUCTION

ShakeAlert encompasses several independent earthquake early warning systems that provide timely earthquake detection and hazard assessment to the Decision Module. The Decision Module provides a unified view of the earthquake in progress using the parameters provided in the event monitor messages and publishes alerts to User Displays that interpret the earthquake information. Currently, Decision Module receives messages from three systems - ElarmS from UC Berkeley, OnSite from CalTech, and Virtual Seismologist from ETH Zurich.



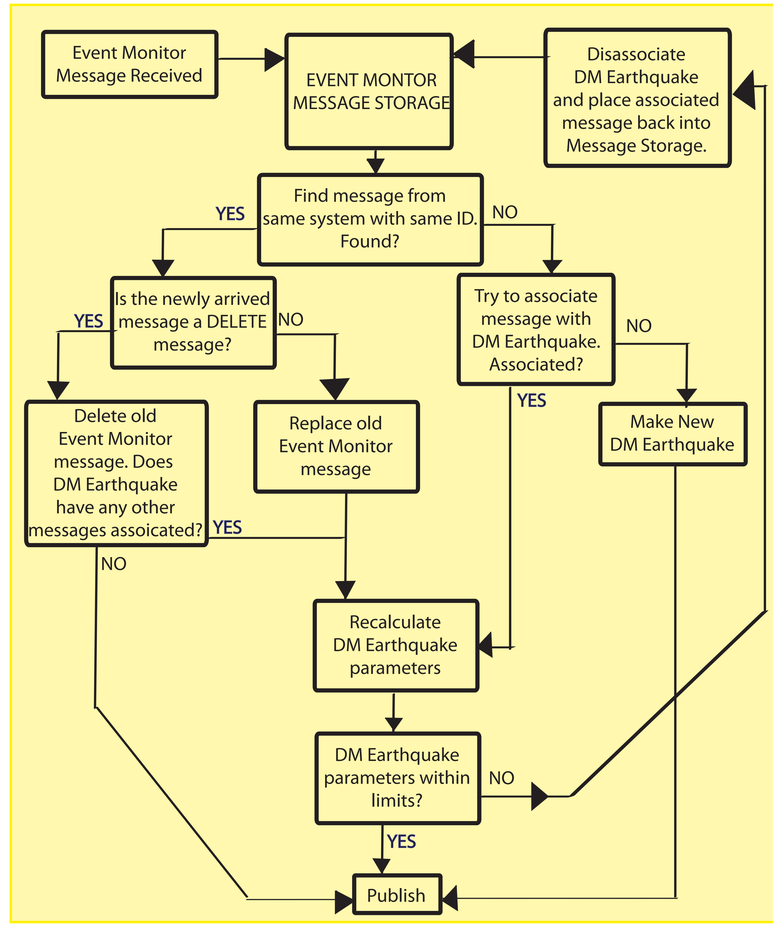
OPERATION

The Decision Module currently uses Java-based ActiveMQ Messaging Broker with C++ Messaging Service extension. Using the XML Format, DM receives messages from ElarmS, OnSite, or Virtual Seismologist earthquake early warning systems. Once DM is informed of a possible earthquake, DM tries to associate the event message with any current event messages that it has stored using a location and time metric. DM does not allow unique messages from the same Event Monitor system to be associated with each other.

If DM doesn't associate the message, it assumes that the newly received message is describing a new earthquake in progress and publishes the earthquake as long as the origin time is close enough to the current time and the warning can be effective.

If DM does manage to associate the message with another earthquake in its memory, it updates the earthquake parameters and publishes the earthquake message to User Display(s) if the change in any of the parameters is greater than a predetermined threshold. The DM will also not publish if it determines that too much time has passed since the origin time of the earthquake. If it is determined that the difference between message parameters of an earthquake exceed acceptable limits, the earthquake is disassociated and messages that made up the earthquake are reassociated individually.

The Decision Module has the ability to receive event messages that delete the previous message in case the Algorithm determines that a false-alarm was issued to the Decision Module.



INPUT/OUTPUT DATA PARAMETERS:
- -magnitude and uncertainty
- -origin time and uncertainty
- -latitude and uncertainty
- -longitude and uncertainty
- -likelihood

OPTIONAL PARAMETERS:
- -peak velocity observation for given channel and time
- -peak acceleration observation for given channel and time
- -predicted peak velocity for given channel and time

EARTHQUAKE PARAMETER CALCULATION:
The formulas on the right show how Decision Module calculates parameters for an earthquake using parameters and the uncertainties provided by the event monitors.

$$M_{likelihood} = \frac{\frac{M_{Elarms}}{\sigma^2_{M,Elarms}} + \frac{M_{VS}}{\sigma^2_{M,VS}} + \frac{M_{OnSite}}{\sigma^2_{M,OnSite}}}{\frac{1}{\sigma^2_{M,Elarms}} + \frac{1}{\sigma^2_{M,VS}} + \frac{1}{\sigma^2_{M,OnSite}}}$$

$$\sigma_{M\ likelihood} = \left(\frac{1}{\sigma^2_{M,Elarms}} + \frac{1}{\sigma^2_{M,VS}} + \frac{1}{\sigma^2_{M,OnSite}} \right)^{-\frac{1}{2}}$$

OUTPUT MESSAGE:

```
<event_message orig_sys=" dm " message_type=" update " version=" 29 ">
   <core_info id=" 686 ">
      <mag units=" Mw "> 3.6118 </mag>
      <mag_uncer units=" Mw "> 10.0000 </mag_uncer>
      <lat units=" deg ">39.0381 </lat>
      <lat_uncer units=" deg "> 5.0000 </lat_uncer>
      <lon units=" deg "> -122.7361 </lon>
      <lon_uncer units=" deg "> 5.0000 </lon_uncer>
      <depth units=" km "> 25.6200 </depth>
      <depth_uncer=" km "> 50.0000 </depth>
      <orig_time units=" UTC "> 2010-12-06T13:57:37Z </orig_time>
      <orig_time_uncer units=" sec "> 20.0000 </orig_time_uncer>
      <likelyhood> 1.0000 </likelyhood>
   </core_info>
</event_message>
```

RESULTS

We have been running the Decision Module for the past two months with all Event Monitors sending messages to the DM. This allows us to provide feedback to the Event Monitor operations. Multiple earthquakes have been successfully associated and published and we are in the process of formal system evaluation.

FUTURE WORK

1. Improve the association of the event messages received from event monitors. There are provisions for using a Bayesian approach to provide the most likely estimate of earthquake parameters and uncertainties.
2. Possibly increase the number of types of messaging systems that can be used for publishing Event Alerts.
3. Integration of current peak values stream into the Decision Module in order to have these observation values be published with the earthquake alert, allowing the User Display to provide more information about the ongoing earthquake.