A Multi-Vector Trust Framework for Autonomous Systems

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Trust in Ad-Hoc Systems and the context of this document

- Particularly interested in the application of Trust in Decentralised (P2P) Autonomous Systems of Systems, Autonomous Underwater Vehicles (AUVs) for example

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  - Operational Trust - the systems within a larger system will perfom as designed in field ✓

Trust Management Frameworks

- Provide information regarding the estimated future states and operations of nodes within networks

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- "[. . .]collecting the information necessary to establish a trust relationship and dynamically monitoring and adjusting the existing trust relationship" -[1]
- Enables nodes to form collaborative *opinions* on their cohort nodes based on
  - Direct Observation of Communications Behaviour (eg Successfully Forwarded Packets)
  - Common-Neighbour Recommendation
  - Indirect Reputation

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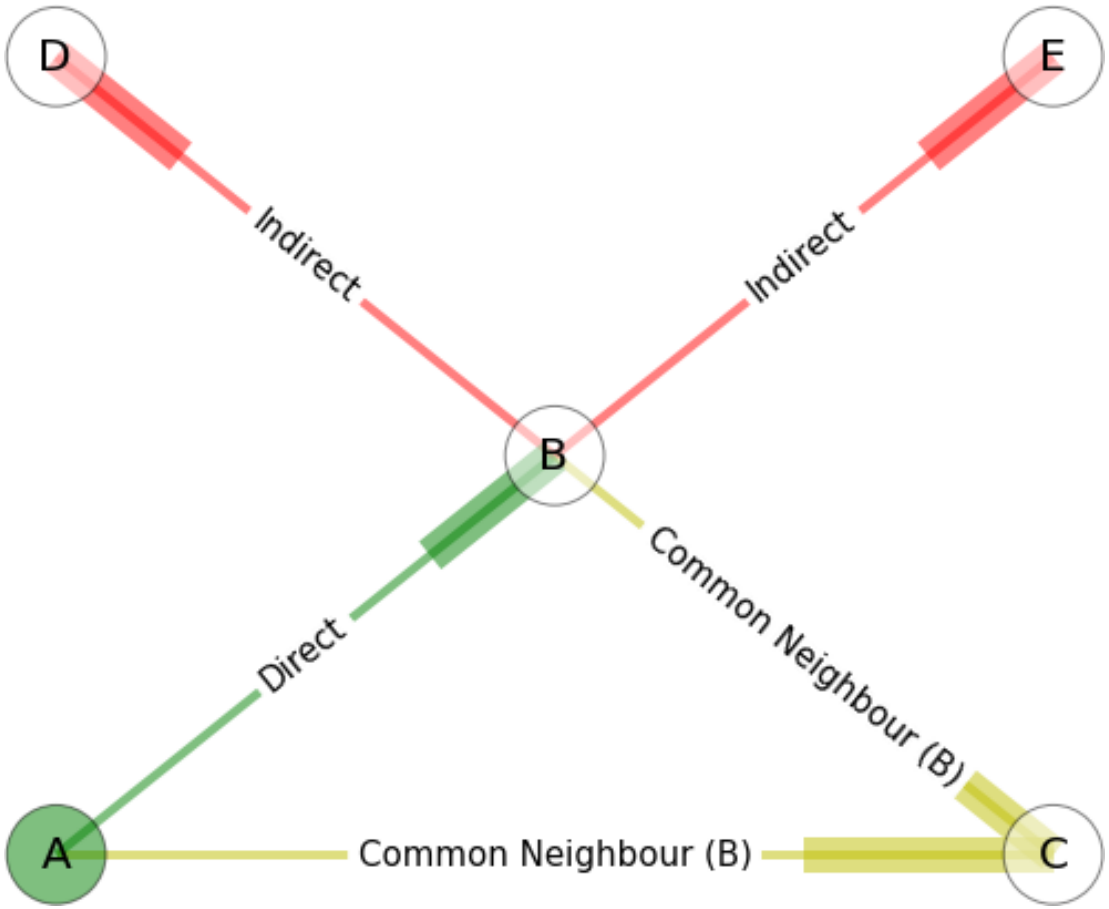
Transitivity in Trust Networks



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- Enable trust establishment from partial-strangers via indirect trust and direct observation
- Enables nodes to inform internal processes for global efficiency given observed network behaviour / 'wellness', similar to those found in human social networks eg
  - Update routing table based on 'safest' node chains (Phone Tree)
  - Maneuver away from misbehaving nodes (Shunning)
  - Inform as to 'trustworthiness' of forwarded information (Healthy sense of Skepticism)
  - Historic Distrust/Trust decaying over time (Forgiveness/Relationship Decay)

Reason for using TMFs in MANETs

- Provide Risk Mitigation against many classical MANET attacks
  - Black/Grayhole
  - Routing Loop
  - Selective misbehaviour / selfishness
- Generally; to constrain potential malicious behaviour that can operate without detection

Trust in Autonomous Systems

- Public Key Infrastructure - Requires Centralised Control and pre-shared keys
- Resurrecting Duckling - Uses in-action keying with a trusted source
- Evidence Based Trust - Uses shared keys
- Reputation Based Trust - Uses Packet forwarding success rate for prediction of future actions
  - CONFIDANT - Trust-based router implementation using packet forwarding rate
  - OTMF - Trust including transitive information from otehr nodes

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  - MTMF - Relationships and Multiple Metrics combined with Gray Interval assessment
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Vectorised Trust

- Application of several individual metrics for the construction of a single trust measurement
- For example:
  - $X = \{packet\ loss, signal\ strength, datarate, delay, throughput\}$
- This multi-parameter trust prevents 'smart' attackers; leveraging a known trust metric to subvert a TMF without detection
- Normally expressed as a vector, but can be condensed into an abstracted or weighted form for comparison [1]

Gray Theory and it's Application in MTMF

- $\left[\theta_{k,j}, \phi_{k,j}\right]^t = \left[\frac{\min_k |a_{kj}^t - g_j^t| + \rho \max_k |a_{kj}^t - g_j^t|}{\max_k |a_{kj}^t - g_j^t| t}, \frac{\min_k |a_{kj}^t - b_j^t| + \rho \max_k |a_{kj}^t - b_j^t|}{\max_k |a_{kj}^t - b_j^t| t}\right]$ [3]
- Basically, scale the individual values against the global maximum and minimum of the sample set to obtain an interval

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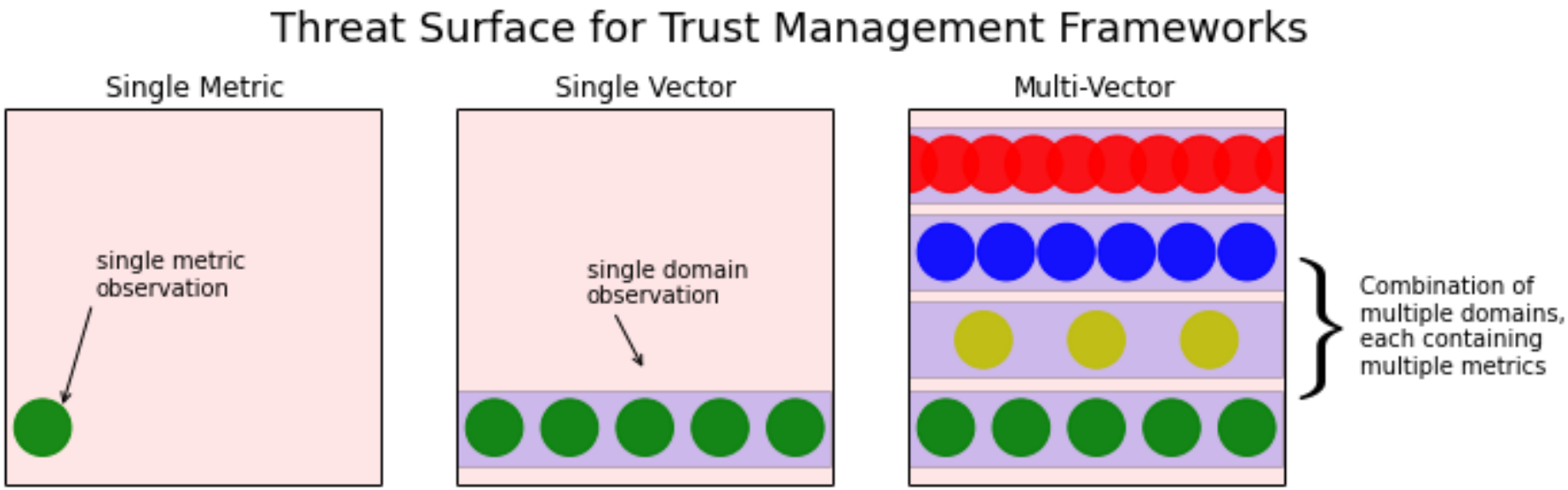
- $\left[\theta_k, \phi_k\right]^t = \sum_{j=1}^{m} h_j \left[\theta_{k,j}^t, \phi_{k,j}^t\right]$
- $T_k^t = \frac{1}{1 + \frac{(\phi_k^t)^2}{(\theta_k^t)^2}}$

  $\mathrm{T}_{k,tot}^t = T_k^t + T_{k,net}^t + (\alpha \times T_k^{t-1} + (1 - \alpha) \times T_{k,tot}^{t-1})$

Multi-Vector Trust and the Threat Surface

Potential attacks exist across a multi-domain threat surface



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  - Inter Node Heading Deviation
  - Inter Node Distance Deviation
  - Node Speed

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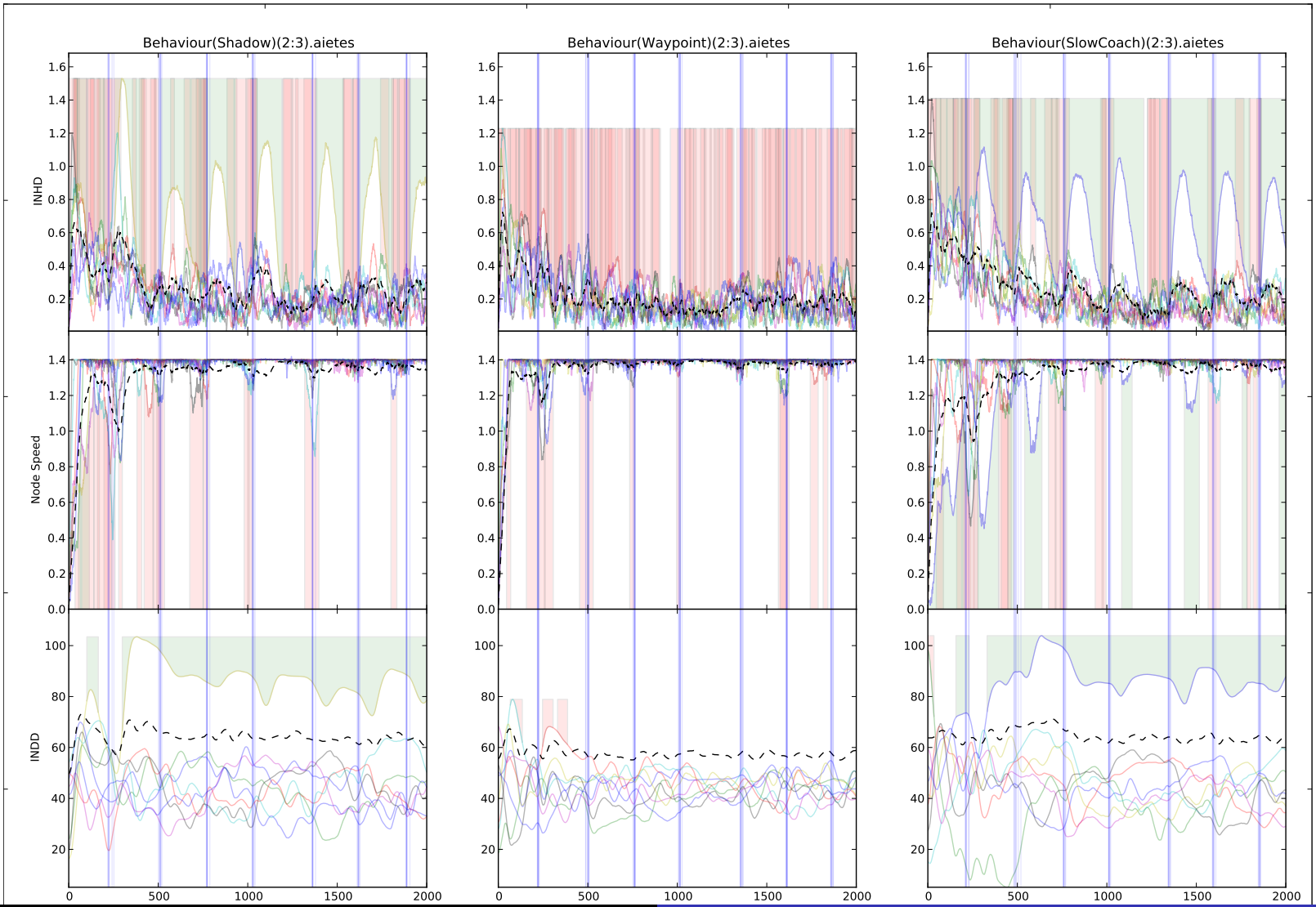
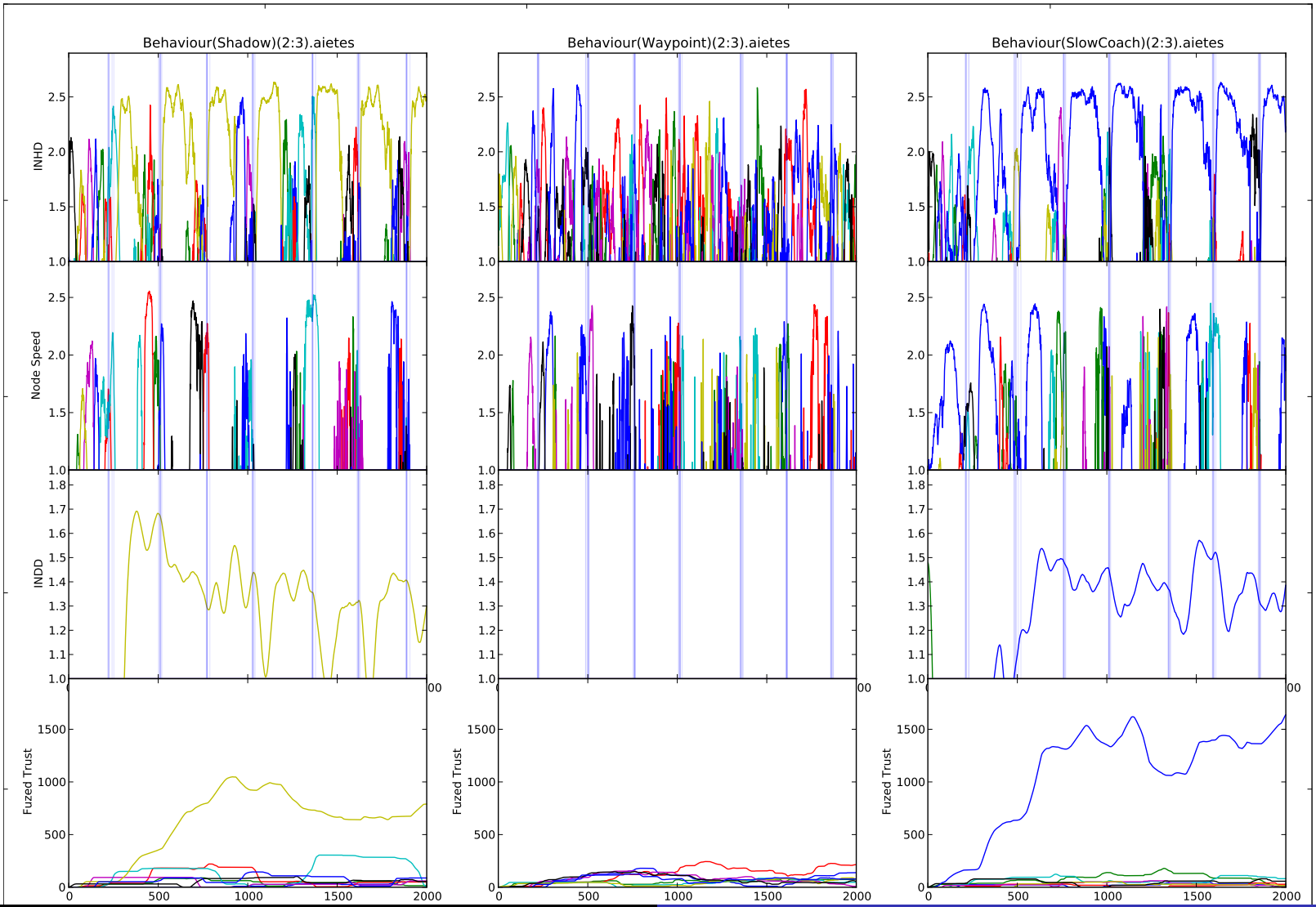
- Metric Selection in collaboration CMRE/DSTL
  - Inter Node Heading Deviation
  - Inter Node Distance Deviation
  - Node Speed
- Behaviour selection for testing
  - Shadow
  - Slowcoach
  - Spy
  - Sloth

Raw Behavioural Metric Assessment in AUVs



Behavioural Trust Assessment in AUVs



Challenges in Multi-vector Trust

- How to define optimality in trust assessment when dealing with multiple vectors and transitive trust?
- Is there a quantifiable benefit to cross-domain comparison beyond single vector Trust?
- Is there an optimal generic cross-domain comparator?

References

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