When Ecosystems Collide: Making Systems of Systems Work

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Context

- A system of systems (SoS) comprises a set of interacting systems that together meet a user's needs but that are independently developed products capable of meeting the needs of other users in stand-alone operation.
  - Operational and Managerial Independence
  - Evolutionary development
  - Emergent behavior
  - Geographic distribution

Hypothesis: Ecosystem analysis adds a dimension that current SoS composition techniques do not have.

Context - 2

- A socio-technical ecosystem is a dynamic community of competing and interdependent people, organizations, and computing systems operating in a complex, capricious environment [Northrop 2006].
- The ecosystem surrounding a software system is a context that includes the influences of collaborating and competing organizations, users, developers, and the domain.

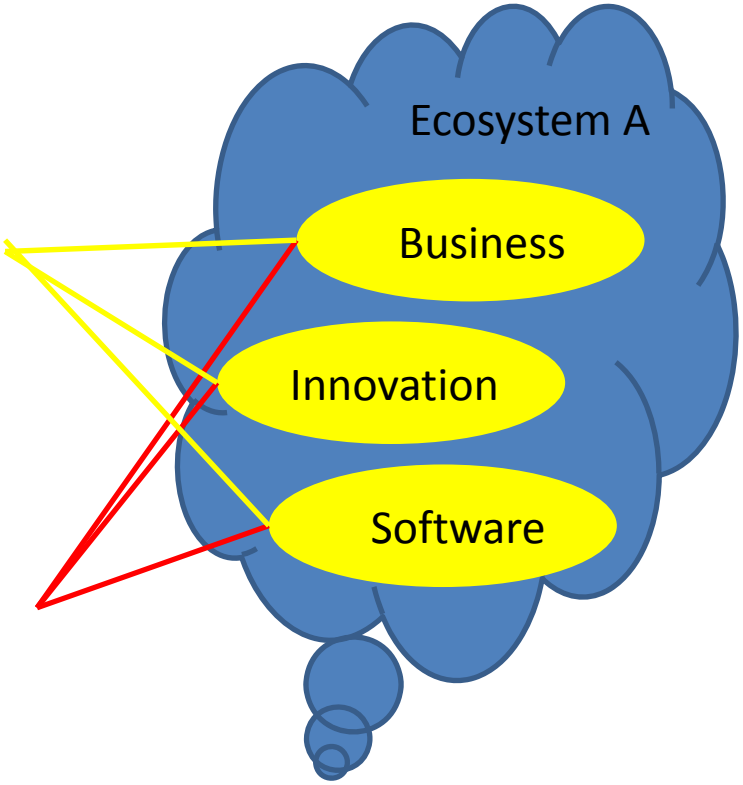
Context - 3

- Every system is part of some ecosystem whether it is explicitly recognized or not
- This influences the success of a SoS

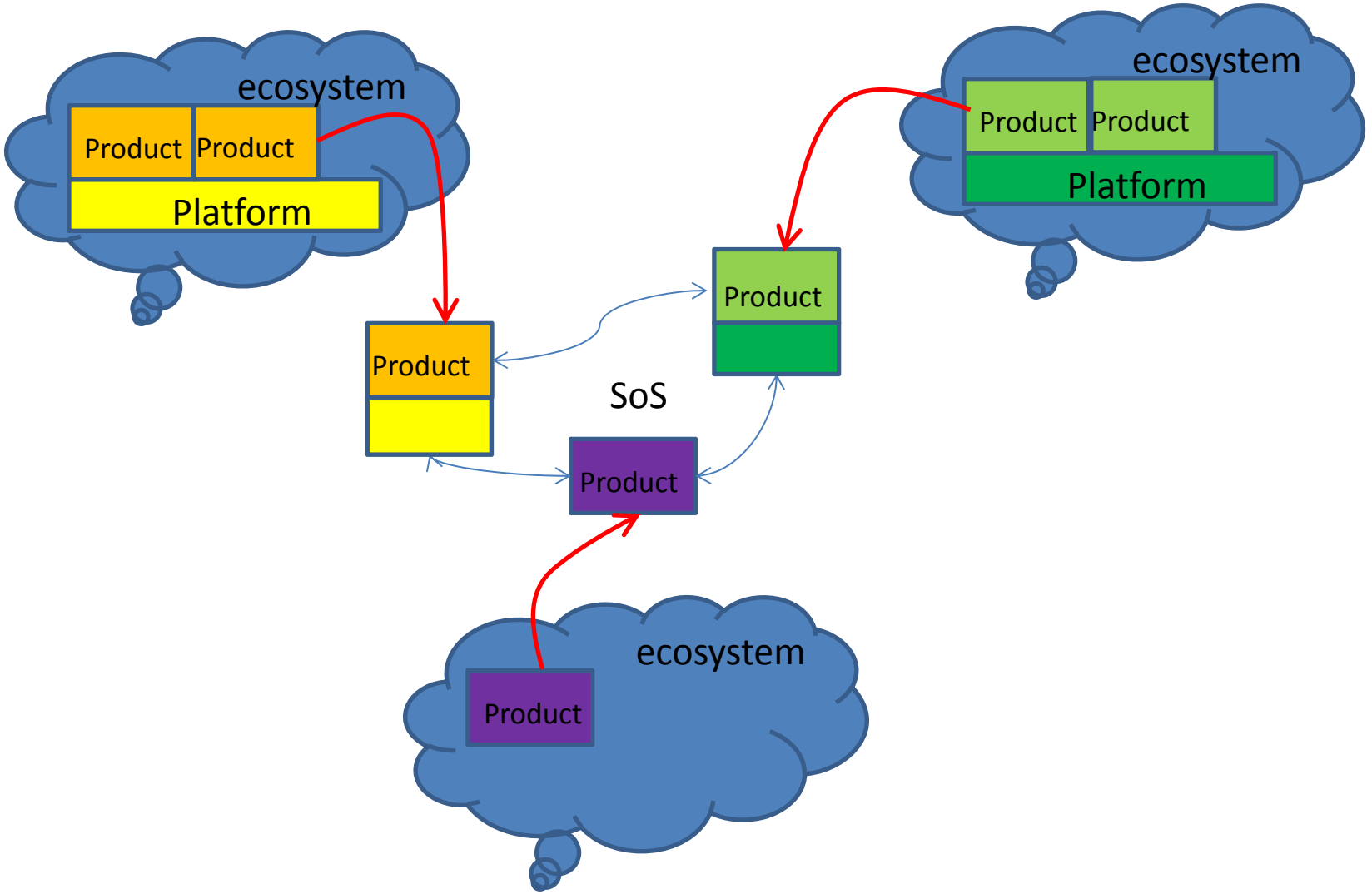
- Knowledge of the ecosystem can inform decisions
- Is this an engineering process? Not yet but the ecosystem strategy covers business, innovation, and software issues

snapshot

longitudinal



A system of systems is composed of products from different ecosystems



Motivation - 1

- US Dept. of Defense has recognized several challenges for composing a SoS:
  - Addressing organizational as well as technical issues in making SE trades and decisions
  - Acknowledging the different roles of systems engineers at the system versus the SoS level and the relationship between the SE done at the two levels
  - Conducting balanced technical management of the SoS
  - Using an architecture based on open systems and loose coupling
  - Focusing on the design strategy and trades both when the formal SoS is first established and throughout the SoS evolution
- We believe our approach using socio-technical ecosystems adds breadth and depth (actually longevity) to the SoS composition process

Motivation - 2

- Many parts of a vehicle are purpose built and do not contribute to the SoS, but
- The basic vehicle is composed with web servers, personal entertainment systems, and positioning systems, which have independent lives, to form the SoS.
- Although a single organization is responsible for the basic vehicle, the vehicle is open to customization via owners or passengers bringing in devices and apps.

GPS

GPS Ecosystems

- Devices implement a standard that is evolving
  - Evolving from general driving directions to precise positioning (down to 1 cm) via satellites
  - Multiple formats for data; can your system handle the latest?
- Autonomous vehicles use GPS for decision making
  - How fast are you closing in on a vehicle?
  - Is it legal where you are to use cell phone?
- Timing of the evolution – when will the increased accuracy be available?
  - The first GPS III satellite was originally scheduled for launch in 2014,[2] but the March 2014 GAO report expects that the first satellite will launch no sooner than April 2016.

Web server ecosystems

- One or more servers (we will worry only about the software) will be running in a vehicle
- This is a mature technology
- Uses the HTTP protocol – a relatively stable protocol with changes being phased in over a long time period and anticipated long before they are deployed
- Will GPS devices using different data formats interface with the web server?

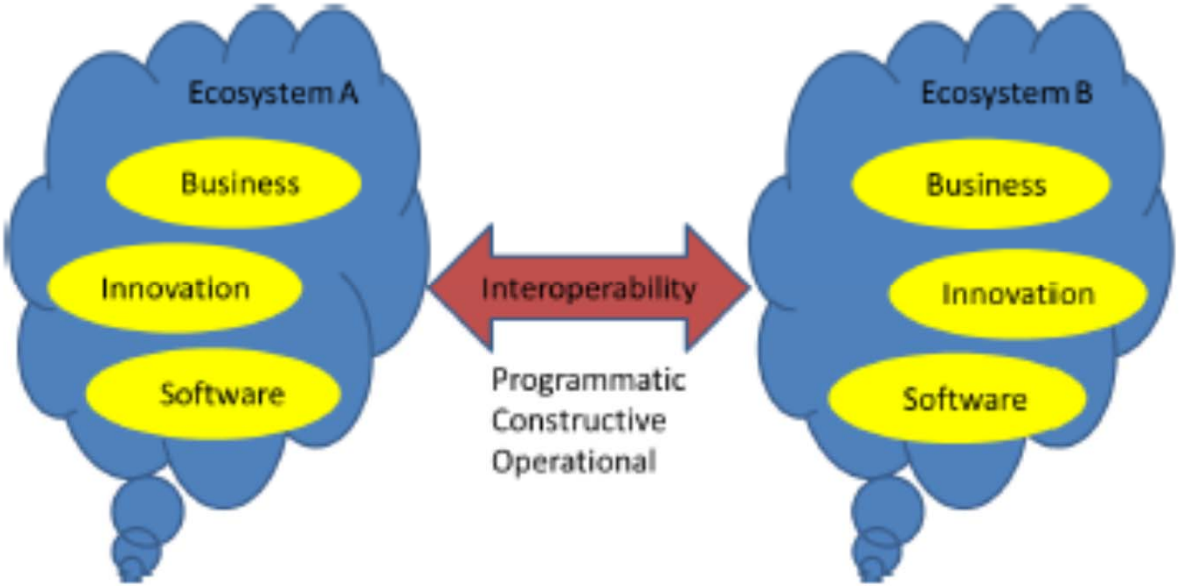
Personal entertainment ecosystems

- Takes content from the web server and provides it to browsers running a web client
- The protocol is so standard there is no need to buy the server and client as a unit
- These devices are changing rapidly but are their interfaces? Memory is expanding. Processors are expanding in numbers of cores.
- Standard operating systems like Tizen protect the server from knowing about the underlying system.
- Streaming of video is needed in both directions

Ethernet connectivity among elements

- Networking is a basic feature of the vehicle
- The GPS, collision avoidance cameras and sensors all must be connected via a network
- There are existing solutions that carry existing protocols, does ethernet?
- Ethernet has the potential to reduce weight in the car and speed up the network, but
- Will OEMs adopt an “open” standard?
- As GPS has more info in its packets can ethernet still meet performance requirements?
- As more connection points are added can ethernet still meet performance requirements?

Systems interoperate in an SoS



- interoperability: the ability of a set of communicating entities to (i) exchange specified information and (ii) operate on that information according to a specified, agreed-upon, operational semantics.

Morris, Ed, Levine, Linda, Meyers, B. Craig, Place, Patrick R. H., & Plakosh, Daniel. System of Systems Interoperability (SOSI); Final Report (CMU/SEI-2004-TR-004, ADA455619). Software Engineering Institute, Carnegie Mellon University, 2004. http://www.sei.cmu.edu/publications/documents/04.reports/04tr004.html

Programmatic interoperability

- “programmatic” here refers to the project within an organization that is composing the SoS (it does not refer to computer programs)
- Business models are compatible? open source can flow to proprietary but not vice versa
  - Licenses appear to be “open” but does not mean compatible necessarily
- Organization may be involved in consortia that are contributing to the one or more systems
- Manufacturers’ ecosystems are robust?

Constructive interoperability

- Standard interfaces are open and compatible at construction time
- Standard interfaces are evolving in compatible direction?
- Alignment of architectures and quality attributes
- GPS has several standard data formats. Either use a single standard or provide converters; Evolution of data formats/standards
- New protocols or new versions of existing protocols need to be compatible
- Ethernet is a new addition to some manufacturers

Operational interoperability

- The systems play nice at runtime
- New protocols or new versions of existing protocols need to be compatible
  - Check timing issues
- Error propagation happens correctly?
  - Use AADL error annex to model

Evolvable architectures

- SoS are usually long-lived systems that take time to compose and are expected to return that investment over its life time
- Standards
  - Formal standards evolve slowly but ad hoc standards can evolve more quickly
- Interfaces
  - How complete are they?
  - Do they represent the standards?
- Continual V&V
  - How agile is the V&V process?

Points of interaction between ecosystems

- Web server is a central point interacting with cellular device, internet connection, vehicle's display technology, vehicle's information system
- GPS device interacts with the web server and vehicle's information system
- Infotainment system interacts with the internet connection through the web server

Open Automotive Alliance

- One solution to the composition problem is to join an emerging ecosystem that will cut across several of the domain ecosystems to offer an abstraction that is a compatible set of systems
- This moves the issue of ecosystem collision away from the specific OEM to the alliance
- www.openautoalliance.net
- http://www.android.com/auto/

Future work

- What are the aspects of the ecosystem that should be considered in composing a SoS?
- How can that information best be used?
- How can existing SoS engineering processes be modified to include this?

Future work - Example Viewpoints

- This is from the Open Distributed Processing development process
- Enterprise Specification
  - Specifies the roles played by an IT system in its organizational environment
- Information Specification
  - Specifies system behavior to meet its objectives abstracted from implementation
- Computational Specification
  - Specifies computational structure in terms of units of functionality and distribution and their interactions
- Engineering Specification
  - Specifies the mechanisms and services to provide the distribution transparencies and meet Quality of Service (QoS) constraints required by the system
- Technology Specification
  - Specifies the hardware and software pieces from which the system is built

http://www.incose.org/chesapek/Docs/2008/Presentations/2008-04-16_McGovern_Global%20Earth%20Observation_System%20of%20Systems_A.pdf