Dynamic Self-Organized Digital Ecosystem Architecture

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Overview of the talk

- Ecosystems
- Digital Ecosystem
- Analogies between Natural Ecosystem and Digital Ecosystems
- Recommender technology for DES
- Architecture of Digital Ecosystems
- Conclusion

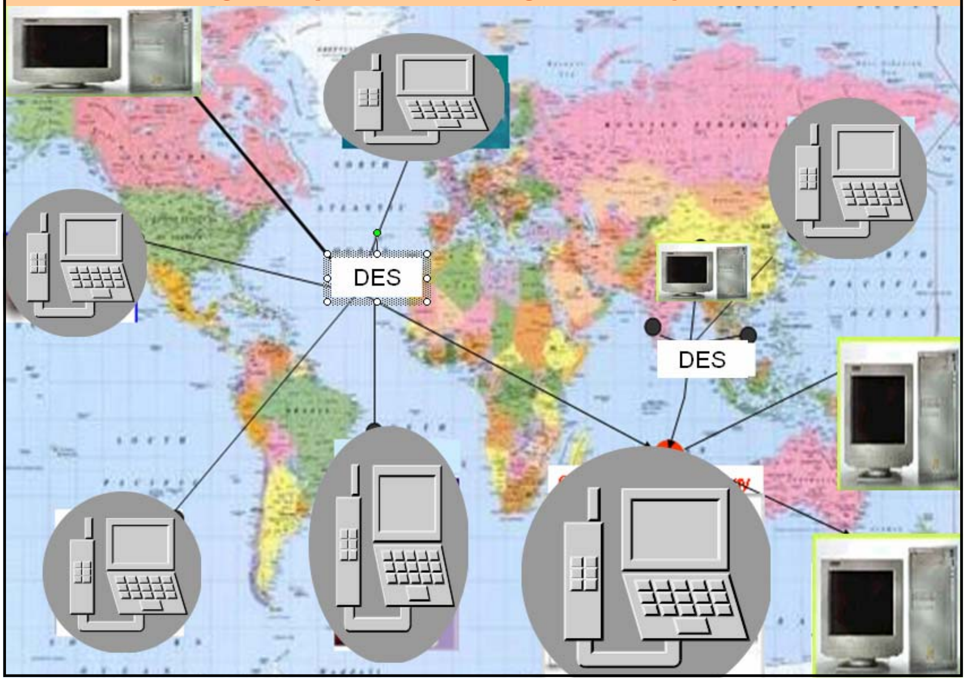
Definition of Digital Ecosystems

Definition of Digital Ecosystem: We define DES as an open, loosely coupled, domain clustered, demand-driven, self-organizing agent environment, where each agent of each species is proactive and responsive regarding its own benefit/profit but is also responsible to its system.

Digital Ecosystem Concepts

1. **Collaboration**: collaborative parties working together on common, agreed tasks or goals, coordination, cooperation, support or help
2. **Self Organising**: independent, self-empowered, self-prepared, undertakes self-defence, is self-surviving and undertakes self co-ordination through swarm intelligence. In case of natural disaster one can not ask 'where is the president', 'what logistics systems are provided' and so forth.
3. **Proactive**: full of enthusiasm to participate in team work or community work
4. **Responsive**: demonstrates willingness, passionate about the issues, cooperative and takes responsibility for its action
5. **Benefit**: advantage that an agent can take without any risks (gaining profit, increase finances, taking advantages, getting promotion, obtaining bonus etc.)
6. **Profit**: personal financial gain.

Digital Species and Digital Ecosystems



Species

- Species in an ecosystem come from the same domain, rather than a traditional, collaborative environment where mixed domains co-exist.
- Species in an ecosystem are autonomous agents. They participate in the community of their own initiative.
- Species are heterogeneous and encompass loosely coupled relationships within an ecosystem. Unlike traditional networked environments where entities or objects are carefully blended together and the community encapsulates all individuals.
- Species share commonly agreed vocabulary and they communicate knowledge through *commonly shared ontology*

The environment

- The platform for supporting the species
- Provides (and/or) supports an underlying knowledge base through ontologies to support information communication that enables shared understanding of concepts.
- Provision of self-organising, self-empowered, self-prepared, self-survival, self-coordination, aimed at creating a sustainable environment for networked organisations or agents.

Natural Ecosystem

- An *ecosystem* is a loosely coupled, domain clustered environment inhabited by species, each proactive and responsive regarding its own benefit while conserving the environment (Boley et al, Chang et al)
- *Species* need to interact with each other and balance each other
- The *environment* supports the needs of its species so they can continue generation after generation.

Essential Aspects of Ecosystems

- Interaction and engagement
- Balance
- Domain Clustered and loosely coupled
- Self-Organized

Recommender Systems in DES

- Makes use of trust based decision making
- Leverage trust and reputation technology
- Alleviates the risk of interacting with a potentially untrustworthy partner
- Key issues to be taken into account when making trust based decision
  - Context-Specific Nature of trust
  - Dynamic Nature of trust

Trustworthiness Scale

Trustworthiness Level	Semantics	Mapping between Trustworthiness Levels and Trustworthiness Values	Trust values range (Trustworthiness Value range)	Visual representation
1	Totally or completely Untrustworthy	-1	$-1 \le x < 0$	Not displayed
2	Untrustworthy	0	$0 \le x < 1$	Normally, not displayed
3	Minimally trustworthy	1	$1 \le x < 2$	★
4	Neutrally Trustworthy	2	$2 \le x < 3$	★★
5	Partially Trustworthy	3	$3 \le x < 4$	★★★
6	Trustworthy	4	$4 \le x < 5$	★★★★
7	Completely Trustworthy	5	5	★★★★★

Table 3.2. Trustworthiness levels and their semantics representation.

Modelling and Managing the Context-Specific Nature of trust

- Both the interacting species enter into a ‘negotiation phase’
- We define the *context of an interaction* as a means of representing broadly the set of all the coherently related functionality(ies) or activity(ies) that the trusting specie is looking for in an interaction with the trusted specie.
- The context of an interaction can be additionally described as a high level summarized description of all activity(ies) or functionality(ies) that the trusting agent is looking for in its interaction with the trusted entity.

Negotiation Phase

- The first stage in a prospective interaction between the trusting specie and the trusted specie.
- Steps in the negotiation phase:

  Step 1: Initial Interaction Proposal from the trusting specie

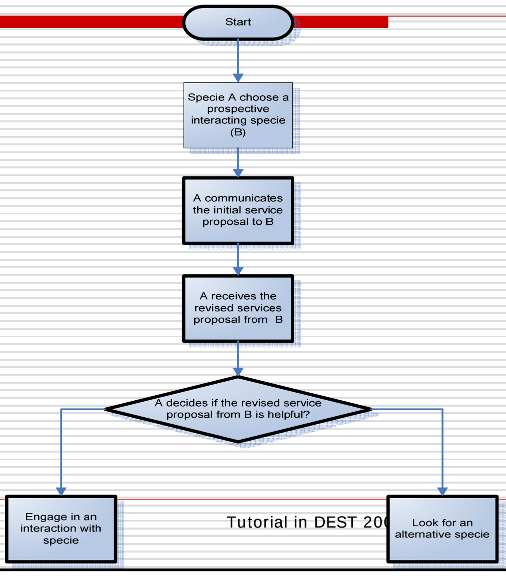
  Step 2: Revision of Interaction Proposal from the trusted specie

  Step 3: Revision of Interaction Proposal from the trusting specie

  Step 4: Agreeing on an interaction proposal or looking for an alternative specie

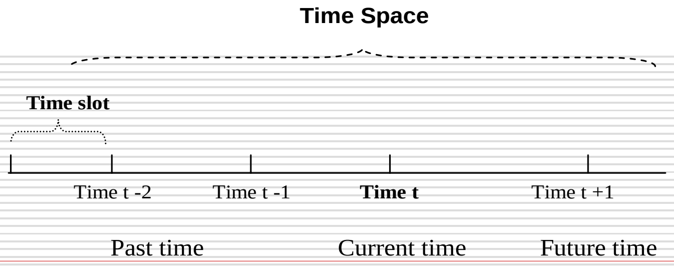
  Step 2 and Step 3 collectively form an iteration
- The trusting specie and the trusted specie may need to go through a number of iterations in order to agree up on or determine the interaction proposal.

Pictorial Representation of the Negotiation Stage in order to determine the context



Modelling and Managing the Dynamic Nature of trust for recommender systems

- **"a given time slot"** captures the dynamic nature of the trust relationships. The belief or confidence is never static.
- the **trustworthiness** is a dynamic numeric value that communicates the strength of the trust relationship in a given time slot.



Making trust based decision

- Broadly speaking the trusting specie may want to make trust based decision:
  - During the current time slot
  - During the future time slot

Trust Based decision making during the current time slot

- The trusting specie needs to determine if the trusted specie has a trustworthiness value greater than equal to 6
- If that is the case then the trusting specie can interact with the trusted specie

Predicting the future trustworthiness value of the trusted specie by the recommender system

- Step 1: Determine time space and length of each time slot
- Step 2: Solicit recommendations for all the time spots with in the slot space
- Step 3: Aggregate recommendations for each time slot

Aggregating recommendations in each time slot

$$R_{k,i} = \left(\sum_{J=1}^{P} Rep_{i,j} - Dir_{k,j} \right) / P \ldots\ldots\ldots\ldots\ldots(1)$$

Where, k denotes the reputation querying peer;
j denotes the reputation queried peer;
i denotes the witness peer;
$Rep_{i,j}$ denotes the recommendation value communicated by peer i about peer j;
$Dir_{k,j}$ denotes the actual trustworthiness value that peers k assigned to peer j based on direct interaction;
P denotes the number of peers (witness peers) about whom the reputation querying peer (j) so recommendations from the reputation queried peer (i).
$R_{k,i}$ is numeric value that denotes the extent to which peer I gives correct recommendations to peer k. We ca coefficient **repute coefficient.**

Reputation Series

Step 4: Construct a reputation series

Step 5: Construct the current state vector

Step 6: Construct Markov Matrix or Transition Matrix

Step 7: Construct the future state vector

Step 8: Make trust based decision based on the future trust value

Reputation Series.. Contd

- May exhibit trend
  - Steady Upward trend
  - Steady Downward trend
  - Steady Irregular Downward trend
  - Steady Irregular Upward trend
- May exhibit seasonality components
- May exhibit noise

Assigning trustworthiness value after interaction

- Four key metrics are used to express both quantitatively and qualitatively the trustworthiness value of an entity
  - Correlation of Interaction ($Corr_{Interaction}$)
  - Correlation of Criteria ($Corr_{Criteria}$)
  - Importance of Criteria ($Imp_{Criteria}$)
  - Clarity of Criteria ($Clear_{Criteria}$)

Assigning trustworthiness value after interaction

- Determine a weighted average of the fulfillment of all the criteria in the interaction
- Based on the computed value future trust based decisions can be made

Evolution of Digital Ecosystem Architecture

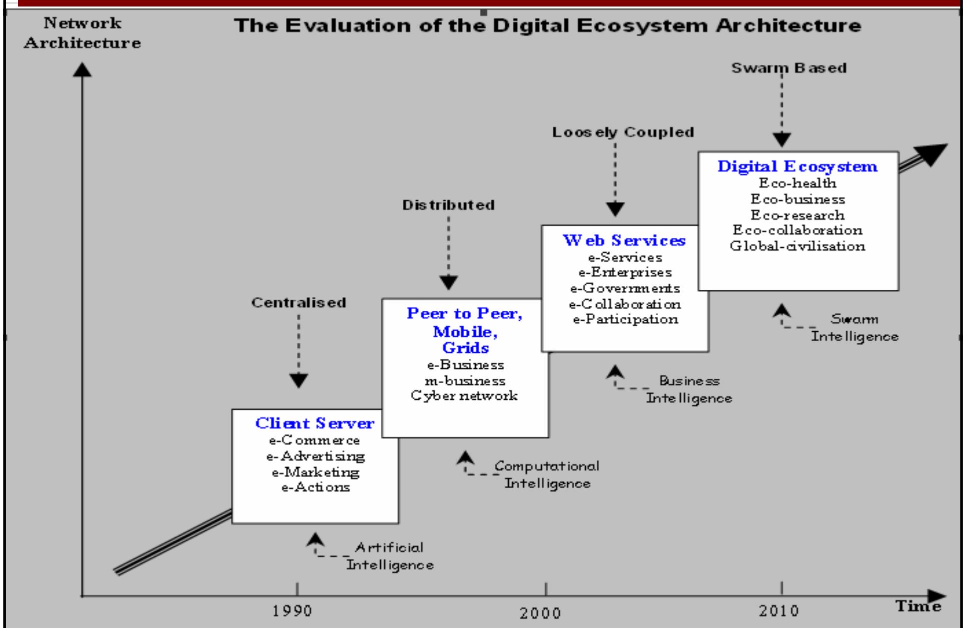
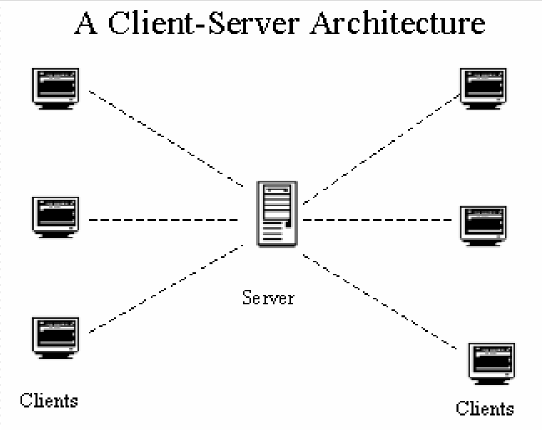


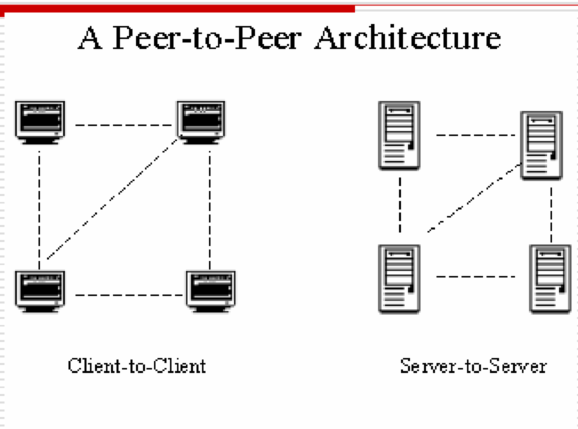
Figure 5 Evolution of Digital Ecosystem Architecture

Evolution of Digital Ecosystems Architecture



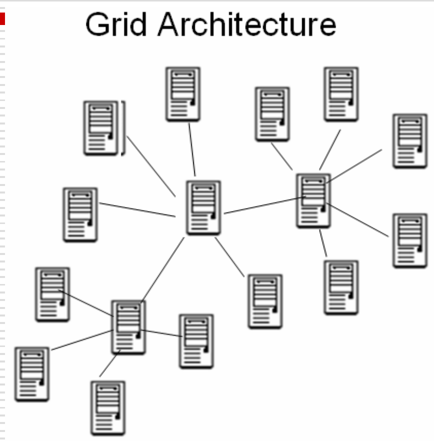
One acts as the server, others act as clients

Evolution of Digital Ecosystems Architecture



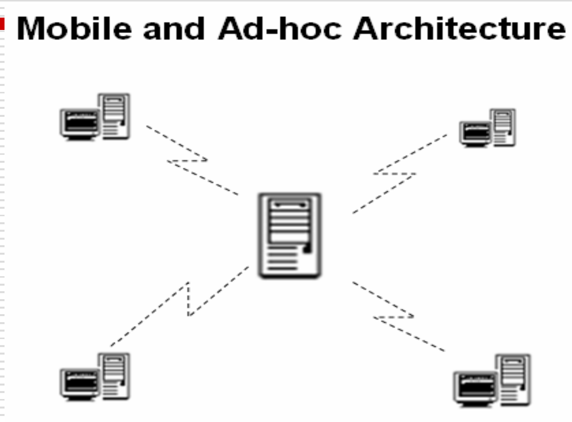
Each has same roles and functions

Evolution of Digital Ecosystems Architecture



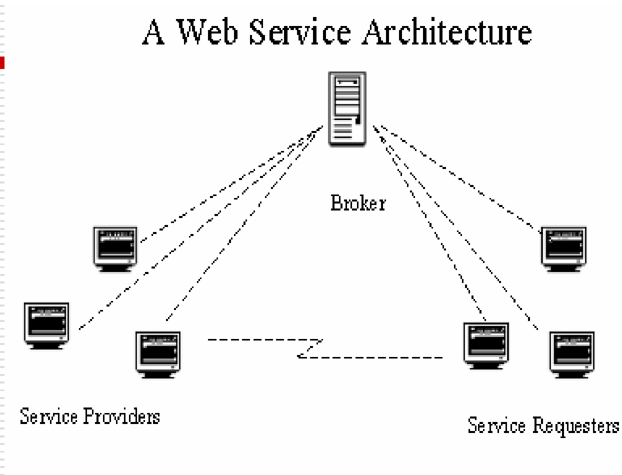
Stitch partner together to share each others resources

Evolution of Digital Ecosystems Architecture



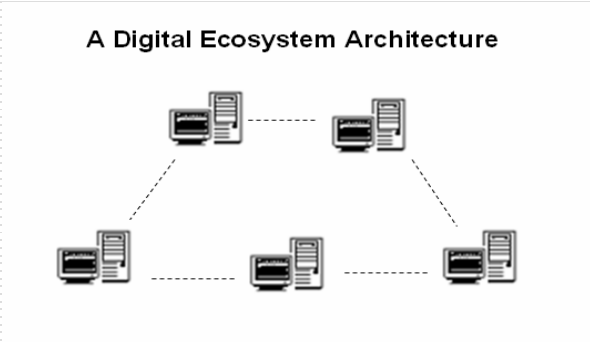
Session based, small networks, temporary connections

Evolution of Digital Ecosystems Architecture



Hybrid, Centralised and P2P Architecture

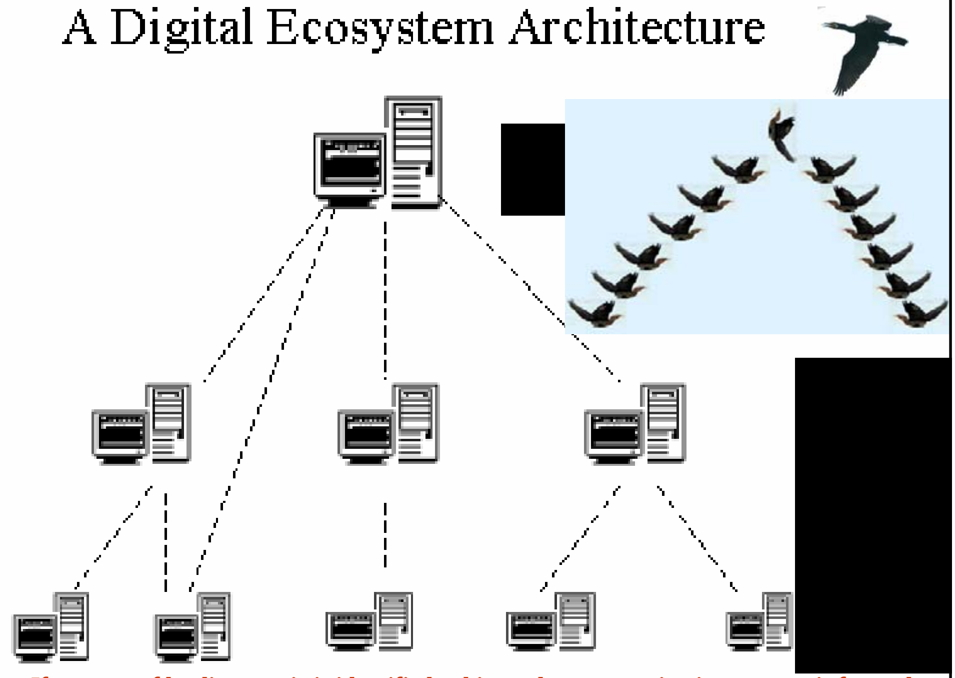
Digital Ecosystems Architecture



Dual roles, loosely coupled, self-organized, dynamic architecture

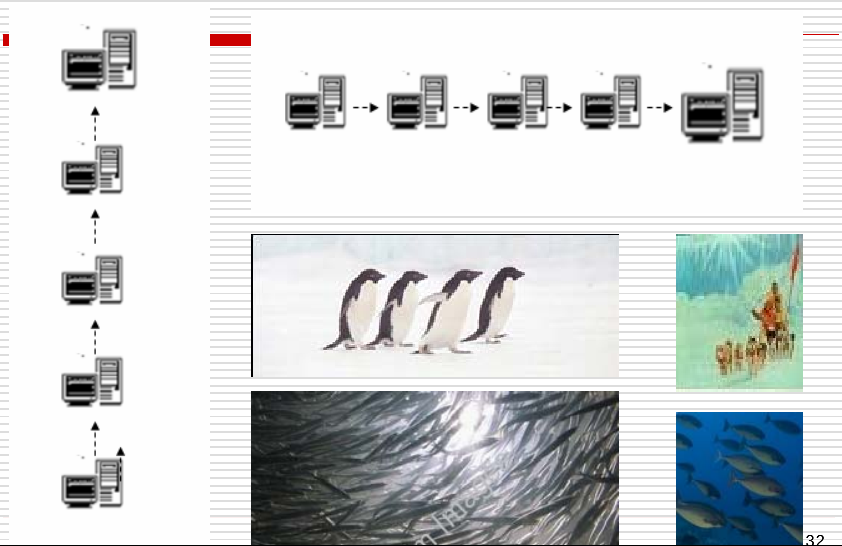
There is no permanent or fix architecture or roles for the species

A Digital Ecosystem Architecture



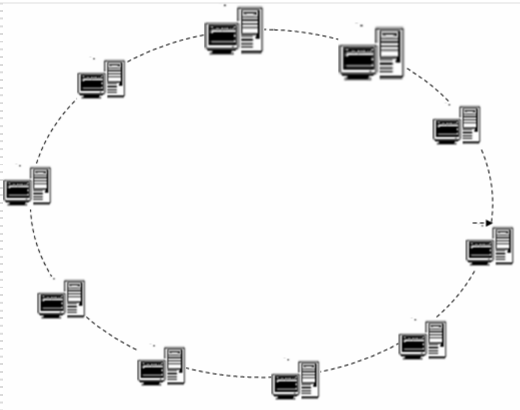
If a group of leading specie is identified, a hierarchy communication pattern is formed

Digital Ecosystem Architecture Cont’



If a leading specie is identified, a liner communication patern is formed

Digital Ecosystem Architecture Cont’



Digital Ecosystem Architecture

A Swarm Intelligent based

A *swarm* is a set of species which has common characteristics and are able to interact and engage directly or indirectly with each other. They collectively carry out a task or share the problem.

Swarm Intelligence is an important property of ecosystems. We often see a collective behaviour of species or agents interacting with each other and the environment and generate a coherent functional global pattern.

Swarm Intelligence is now widely researched as it provides a basis to explore collective behaviour for problem solving without centralised or command and control systems and the provision for flexible, dynamic interactive models.

Compare and Contrast

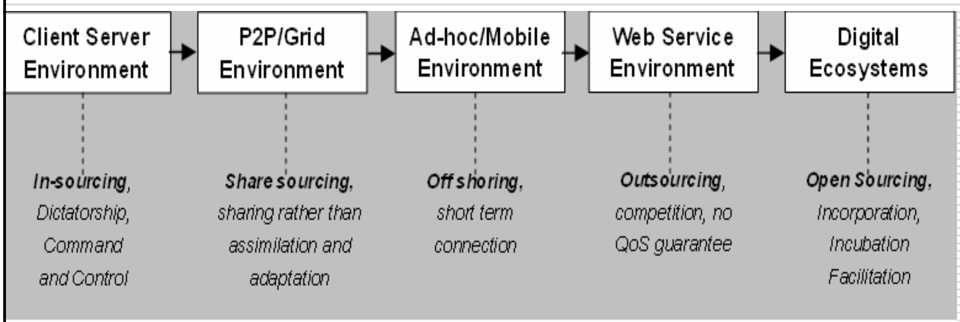
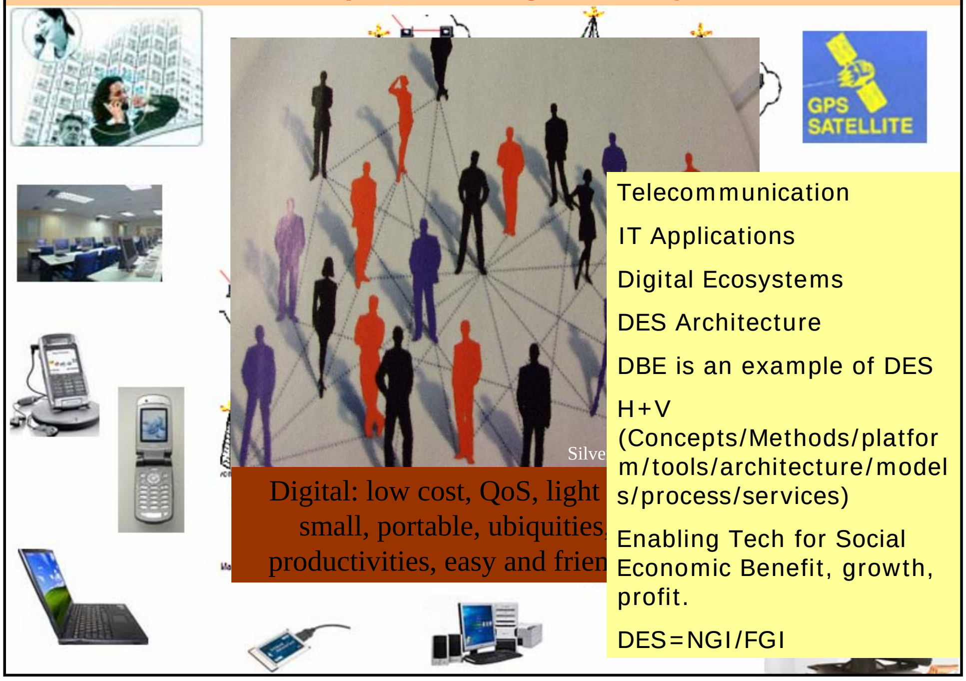


Figure 8 The advances in Digital Ecosystems

Compare and Contrast

	Client-Service Environment	Peer to Peer Environment	Grid Network	Web Services Environment	Digital Ecosystems
Model	Centralised	Distributed	Distributed	Hybrid (centralised and distributed)	Swarm based distributed swarms
Composition	Several clients and 1 server	Peers	Notes	Broker, service providers, service requester	Species or Agents
Roles	Either Client or Server, and cannot be changed	Each peer carries a single role and the role cannot be changed	Obey Service Level Agreement	The entity has a well defined role and cannot be changed	Each species or agent has dual roles, it can be a client or a server
Architecture Foundation	3 Tier architecture	Ad-hoc distributed computing	Middleware	SOA Service Oriented Architecture	Swarm intelligence, ontology and agents
Communication	To or from a central server	RFC (Request for Comments) download/uploads	On demand access	Request, find and bind	Supply and demand
Goals	e-Commerce, central information repository	File sharing, anonymous communication	Resource sharing	e-Business, e-services	Collaboration, cooperation, balance, growth, and prosperity

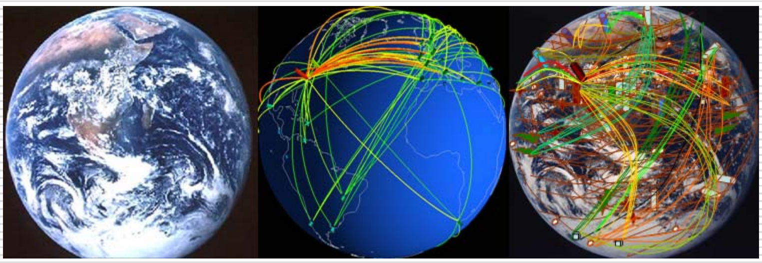
Possible Species in Digital Ecosystems



Digital: low cost, QoS, light small, portable, ubiquities, productivities, easy and frien

- Telecommunication
- IT Applications
- Digital Ecosystems
- DES Architecture
- DBE is an example of DES
- H+V (Concepts/Methods/platform/tools/architecture/models/process/services)
- Enabling Tech for Social Economic Benefit, growth, profit.
- DES=NGI/FGI

Transition from Ecosystem to Digital Ecosystem



Stone Age → Agriculture Age → Industrial Age → Electronic Age → Information Age → Digital Age

Questions, Comments and Suggestions are welcome

Thank you