Digital Ecosystem Architecture

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Abstract: - A digital ecosystem (DES) is new-networked architecture and collaborative environment that addresses the weakness of client-server, peer-to-peer and web services environments. As it is such a new concept, people often assume that it is a type of multi-agent system, or that it is a computer based economic solution or uses a computer to study the ecological system, etc. In this paper, we give an overview of DES, its Architecture, fundamental characteristics and examples of DES.

Key-words: - Digital Ecosystems, Digital Ecosystem Architecture, Characteristics of Digital Ecosystems

1. From collaboration to Digital ecosystems

The key to success of collaboration is that the collaborating parties know what the benefits are before the collaboration begins. Especially the active party has to convey this to the passive party and clear spell out the benefits.

Benefit, in common usage, refers to gaining profit, increase finances, taking advantages, getting promotion, or obtaining bonus or free bits etc.

With the advent of Web and its intrusion to business and commerce, has shift the organization from the world of physical connected economy to the digital networked economy and that discharged everyone from traditional individual form or original closed wall organisation operation to an open, dynamic and networked collaborative environment known as Digital Ecosystems.

Collaboration lead to collaborative parties working together on common, agreed tasks or goals and expectation rising on the level of coordination, cooperation, support or help is given by other parties during the collaboration period. The collaboration lasts as long as the expectation is satisfied. Today's collaboration is mostly carried out over the Internet and through the utilisation of ICT to support communication, coordination and cooperation rather than face-to-face or physical encounters. This new form of collaboration environment is known as Digital Ecosystem.

2. Existing Collaborative Platform Architectures

One key component of the collaboration is communication. It helps iron out misunderstandings, just-in-time problem solving and solution development through electronic means (such as information access and sharing, documents management, visual representations, knowledge discoveries, track-n-trace tasks, projects and issues). Therefore, various ICT infrastructure, platforms or tools are available to help ease communication, namely: centralised client-server approaches, distributed and mobile network based approaches. These are explored below.

The *client-server architecture depicts that* one computer acts as the server and others act as clients. This digital infrastructure defines that there is only one server in the collaborative environment and who can access it. Everyone else is a client only, and this role of communicating parties (either clients or server) is clearly defined from the beginning. For example, a client cannot be changed to a server for the same transactions once the infrastructure is set up [10].

The *Peer-to-Peer (P2P) Architecture* denotes that each computer has the same roles and functions [31]. A P2P network distributes information among the nodes directly instead of interacting with a single server [25]. P2P supports heterogeneous systems [29]. Each node has its own repository for distribution to other nodes. There is no central repository in a P2P network as information is automatically spread in the network [31]. Napster, Gnutella, Kazaa and Freenet are amongst the most popular P2P applications [32]. For an anonymous network, the identity of the node is unknown [19] Among the four most popular applications, as

previously mentioned, *Freenet* provides anonymity in accessing the network [32].

Grid *Architecture* assembles the existing components and information resources in order to be able to share them among the users [26]. The Grid Network provides a resource-sharing paradigm for clients. In particular, the grid network is a collection of servers and clients working together [15]. Each node is autonomous. There is no central management. A grid network is similar in a few respects to P2P in that they both provide the sharing of resources and components among the nodes in the network [20]. Even though the grid network supports heterogeneous systems, to integrate enormous numbers of heterogeneous components and resources it is expensive and with the current available technology poses difficulties.

Mobile network architecture provide infrastructure for user to access to the Network whatever they want without being tied to a fixed location PC, as they change their geographical location, using compact devices such as PDAs, smart phones and Internet appliances [35].

An *ad-hoc network* is a local area network (LAN) or small network, where the connection is temporary. The communicating parties are in the network only for the duration of a communication session.

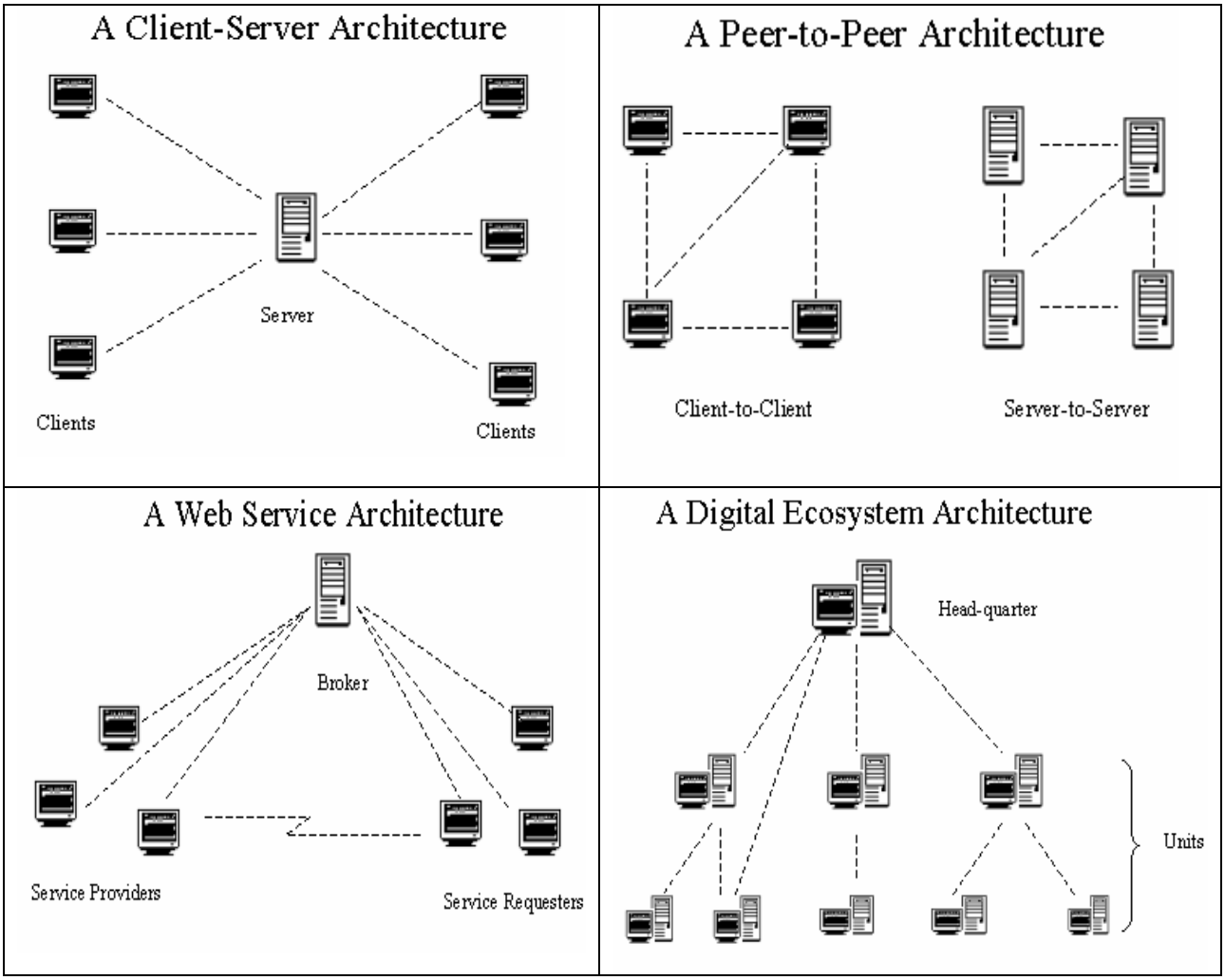

Figure 1. Digital Ecosystems Architecture and its comparison to other existing Architectural styles

3. Digital Ecosystem Architecture

In an ecological system environment, we consider species analogous to biological species creating and conserving resources that humans find valuable. The software, databases, applications or software services in digital ecosystems are referred to as *digital species*.

Economic species in analogy with biological species, such as business entities, together form a dynamic and interrelated complex ecosystem. The *complex ecosystem* is defined as a composition of mixed multiform, heterogeneous entities participating in domain and carry out cross multi-disciplinary interaction and engagement.

A *Domain* is defined as a specific cluster or colony or field where participants have something in common, such as ocean habitats in Coral Reef in the biological sphere. *Cross multi-disciplinary interaction and engagement* is defined as inter-disciplines interaction, such as coral polyps, tiny animals that live in colonies and together they interact with nudibranchs, fish (such as snapper, clown fish), turtles, sea snakes, snails and molluscs, they together live in warm, open, clear, shallow waters. Sometimes, they work together to defend threats from human interference, pollution, or natural disaster.

A digital ecosystem as a loosely coupled, domain clustered, demand driven collaborative environment where each digital species is proactive and responsive for its own benefit or profit.

3.1 A Conceptual Definition

Therefore, we define a *Digital Ecosystem* as an open, flexible, loosely coupled, domain clustered, demand driven collaborative environment where each digital species is proactive and responsive for its own benefit or profit.

We define *open* as a free transparent environment, where everyone is invited to join except dangerous species that have the intention of causing damage to the community.

We define *flexible* as an easy, tolerable and adaptable environment, with strength to survive peacefully. For example, if coral polyps die, they become a stony, branching structure as part of a reef and can still provide shelter generation after generation.

We define *loosely coupled* as a freely bound open relationship between participants or entities within a virtual community. This term is opposite to the tightly coupled relationship, where each party is heavily dependent on one another and the roles are pre-defined. *Participant* is defined as an entity who wants to join a group or an environment or a community based on its own interest.

We define *domain clustered* as a *colony* or a *field* where participants have something in common or share the same life or interests, such as *ocean habitats* in Coral Reef or exotic tropical plants in a Rainforest Ecosystem.

Demand driven is defined as the driving force coming from outside 'push-in' rather than 'pull-in'. For example, the current networked economy has led supply chains to demand chain, where demand is volatile and supply is uncertain. Another negative example is that the current collaborative environment is not a demand driven environment because humans are told to collaborate and humans may be forced to collaborate. This is not demand driven and a human is forced to be there for the sake of collaboration rather than enjoying collaboration arising from a perceived mutual interest of the parties collaborating. There is no real honest consideration about whether there will be a benefit or profit from the collaboration to the collaborating parties.

Collaborative environment is defined as an environment, which contains human individuals, information technologies that humans can capitalise on; tools that facilitate interaction and knowledge sharing along with resources that help maintain synergy among human beings or software agents.

Human agents and *software agents* in a digital ecosystem are referred to as eco-agents. *Eco-agents* are capable of acting autonomously; often capable of decision-making and responses within the context of a digital ecosystem.

Proactive is defined as an agent or eco-agent that is full of enthusiasm to participate in team work or community work. *Responsive* signifies an agent or eco-agent that demonstrates willingness, is passionate about the issues, is cooperative and takes responsibility for its action.

Benefit refers to an advantage that an agent can take without any risks. *Profit* refers to personal financial gain.

Digital ecosystems transcend the traditional rigorously defined collaborative environments, such as centralised (client-server, where each node in the collaboration network is predefined as either the client or the server and they are highly dependent on each other to perform the function) or distributed (such as peer-to-peer, where each peer is pre-defined as either a peer or a server and communicates only via client-to-client or server-to-server) models. Digital ecosystems, in contrast, are agent-based, loosely-coupled (the participants are free to join the virtual community), domain-specific (the participants have similar backgrounds) and demand-driven (they choose to join the collaboration and determine their own requirements and expectations of the system) interactive communities which offer cost-effective digital services and value-creating activities (every agent or digital species is doing positive things for the

community) that attract agents to participate (it is this freedom and open environment that is attractive) and benefit from it.

A digital ecosystem is a self-organising digital infrastructure aimed at creating a digital environment for networked organisations or agents that support cooperation, knowledge sharing and development of open and adaptive technologies and evolutionary domain knowledge rich environments [38-40] through dynamic interactions within and between different domain clusters and their environment and collaborative effort to remain balanced in the ecosystem environment. It is a business model innovation in the digital economy.

3.2 the Architecture

Digital ecosystem architecture consists of collaborative units (species) only. Units are the basic elements from the digital ecosystem. Each unit can be viewed as an individual or an organisation and has its own niche or role to play. Instead of having clients, peers or brokers in digital ecosystems, we have units. They work together to take care of their living environment.

The *Unit* is an individual or an organisation that demands to participate in the community. The *leading unit* within a digital ecosystem can be named as headquarters who facilitates, leads and directs the collaborative community and may represent the domain cluster in the interaction with other domain clusters (such as animals, humans, plants, earth). But it is just a *Unit* and has the same features and functions as any other unit within the digital ecosystem.

Digital ecosystem architecture is best presented by the comparison with other existing well known collaborative communication architectures. Figure 1 presents four architecture styles: client-server, peer-to-peer, web services and digital ecosystems.

3.3 The Architectural Components

In traditional collaborative environments, the communicating parties such as client, server or peer has well-defined functions. They can either be client, or server for their entire life. However, in digital ecosystems, each unit has dual functions, they can be client and they also can be server. For example, Unit A requests service support from Unit X where X is the server. When X is requesting advice from Unit B, X becomes a client. Therefore, every unit within a digital ecosystem has dual roles. This is the first significance of the digital ecosystems.

The *Headquarter* is the champion or leading species of the domain cluster that leads and develops the collaborative community and is just one of the units within the digital ecosystem, having the same characteristics of other units.

3.4 The Supply and Demand Communication Framework

Instead of communication as request, search, find or bind in traditional collaborative environments, the digital ecosystem units communicate via 'supply' and 'demand' requests. *Supply* is a service that is offered by one of the units for the benefit of the collaborative community. *Demand* is a request from one of the units who is seeking advice, support or help in order to keep up with the rest of the community. If the communication is via supply activities, the unit is currently in a state of being a 'Server'. If the communication calls for a 'request' of a service or support, the unit is currently in a state of being a 'client'.

Another distinction is that in the traditional environment, the direction of communication as 'request', 'find', 'search' or 'bind' is a uni-directional communication and fixed against the role it designated. However, this is not the case in digital ecosystems. The 'supply' and 'demand' requests can be initiated from one unit (ie: X) to any other units (ie: A, B, C) and it is bi-directional (from A, B, C to X).

The collection of different digital ecosystems in the world forms today's digital networked economy. Digital ecosystems are dynamic interactions between domain clusters and their environment working together to preserve quality of life such as fighting diseases, providing better services or enjoying peaceful surroundings. However, if they do not, the networked economy will fail and digital ecosystems will fail because they do not maintain their environment, productivities, prosperity and balanced life (see Figure 2 below).

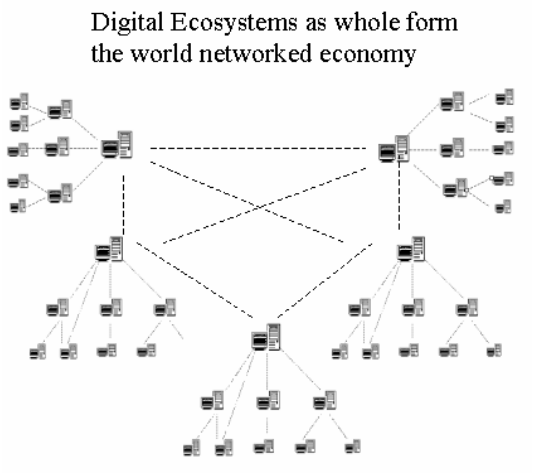

Figure 2. The Biome of Ecosystems

3.5 Characteristics of Digital Ecosystem Architecture

Several factors characterise a digital ecosystem architecture; namely:

- It has a strong information infrastructure that extends beyond the original closed walls of the individual organisation.
- It is a domain-oriented cluster, which forms an interactive community that attracts similar species, which challenge and support each other to survive.
- It contains rich resources that can offer cost-effective digital services and value-creating activities for the participants.
- It utilises new forms of electronic interaction, provision of digital services and use of services.
- It carries high connectivity and electronic handling of information of all sorts including data and documents.
- It offers multiple channels for buying and selling of services.
- It captures and utilises business intelligence from data, documents and other agents and has smart information use.
- It is an integration of business, human endeavours and advanced information systems within the digital ecosystem.
- It facilitates close interaction between participants and cross fertilisation and nourishes each other and supports different needs within the digital ecosystem and between different digital ecosystems.
- It is a cross-disciplinary interaction and engagement, which offers a mix of expertise that preserves and enhances productivity, prosperity and international competitiveness.
- There is always an underlying knowledge base available to support information communication that enables shared understanding of concepts.
- Information is highly distributed, heterogeneous and massive, like a huge library without a catalogue system.
- Ecosystem participants or agents are autonomous, highly interrelated and dynamic and able to coordinate among themselves.
- 'A digital ecosystem is a self-organising digital infrastructure aimed at creating a digital environment for networked organisations (or agents) that support cooperation, knowledge sharing, and development of open and adaptive technologies' and 'evolutionary domain knowledge rich environments' [15].

The European Union defined digital ecosystems as a new initiative [40] and announced 'Innovation Ecosystem Initiative' as part of the European Seventh Framework Proposal and part of the i2010 initiative [38]. It is also noted that there will be an inaugural IEEE International Conference on Digital ecosystems and Technology to be held in Cairns, Australia in February 2007 (www.IEEE-DEST.curtin.edu.au). This demonstrates the innovation and significance of the research at international level.

4. Conclusion

This paper provided an extensive explanation of digital ecosystems, their architecture and comparison with most advanced information communication platforms or environments such as client-server, P2P and web-services. We also gave examples such as digital business ecosystems and digital health ecosystems. We hope that this paper will help worldwide researchers to further understand and broadly apply digital ecosystem ideas, principles and architecture in business, government and other domain disciplines to preserve and enhance the productivity, growth, prosperity and international competitiveness.

References

1. Doukidis, G.I., Mylonopoulos, N. & Pouloudi, N., 2003 (EDT) '*Social and economic transformation in the digital era*', Idea Group International, ISBN: 1591402670
2. European Commission, 2006, '*Innovation ecosystems – A specific roadmap*', DG Information Society and Media.
3. Denning, P.J. & Metcalfe, R.M., 1998, '*Beyond calculation: The next fifty years of computing*', (edited) Springer, ISBN: 0387985883
4. European Commission, 2006, '*Technologies for digital ecosystems – Innovation ecosystem initiative*', available at http://www.digital–ecosystems.org

5. Chang, E., Dillon, T.S. & Hussain, F.K., 2005, *'Trust and reputation for service-oriented environments'*, John Wiley and Sons, UK, ISBN: 0-470- 01547-0
6. http://www.w3.org/Collaboration
7. http://www.partnershiptool.net/samplePAT.htm 'Sample questionnaire for partnership self-assessment tool'
8. Fishman, M., et al., 2000, '*Valuating community collaborations: A research synthesis'*, Lewin Group, Inc, USA.
9. http://www.edgelab.ca/CSCW/Workshop2004/WorkshopNotes.pdf
10. Chang, E., Dillon, T.S. & Hussain, F., 2005, **'***Trust and reputation for service oriented environments- Technologies for building business intelligence and consumer confidence'***,** John Wiley & Sons, ISBN: 0-470- 01547-0
11. Algesheimer, J., Cachin, C., Camenisch, J. & Karjoth, G., 2000, '*Cryptographic security for mobile code'*, IBM Research, Zurich, Switzerland,
12. Alonso, G., Casati, F., Kuno, H. & Machiraju, V., 2004, '*Web services: Concepts, architectures and applications'*, Springer, Berlin.
13. Alston, J., Hess, D. & Ruggieo, R., 2002, '*UDDI (Universal Description, Discovery, and Integration) and web services: Perspective*', Gartner.
14. amazon.com (2004), '*Web service'*, Available: [http://www.amazon.com/gp/browse.html/103-6530699-8373443?node=3435361] (Aug 24, 2004).
15. Berman, F., Fox, G. & Hey, A., 2003, 'Overview of the book: Grid computing - making the global infrastructure a reality', in Berman, F., Hey, A. & Fox, G. (eds.), '*Grid computing - making the global infrastructure a reality'*, John Wiley & Sons, Ltd.
16. Carrol, A., Juarez, M., Polk, J. & Leinger, T., 2002, '*Microsoft palladium: A business overview'*, Microsoft whitepaper, June 2002. http://www.microsoft.com/PressPass/features/2002/jul02/0724palladiumwp.asp.
17. Cerami, E., 2002, '*Web services essentials'*, O'Reilly & Associates, Inc., Sebastopol.
18. Cruz, S. M. S., Campos, M. L. M., Pires, P. F. & Campos, L. M., 2004, '*Monitoring e-business web services usage through a log based architecture'*, Proceedings of the IEEE International Conference on Web Services (ICWS'04).
19. Foster, I., Kesselman, C., Nick, J. M. & Tuecke, S., 2003, 'The physiology of the grid', in Berman, F., Hey, A. & Fox, G. (eds.), '*Grid computing - Making the global infrastructure a reality'*, John Wiley & Sons, Ltd, pp. 217-249.
20. Gannon, D., Ananthakrishnan, R., Krishnan, S., Govindaraju, M., Ramakrishnan, L. & Slominski, A., 2003, 'Grid web services and application factories', in Berman, F., Hey, A. & Fox, G. (eds.), '*Grid computing - Making the global infrastructure a reality'*, John Wiley & Sons, Ltd, pp. 251-264.
21. Hassler, V., 2001, '*Security fundamentals for e-commerce*', Artech House.
22. Hess, D., 2002, '*Simple object access protocol (SOAP) and web services: An introduction*', Gartner.
23. Huy, H. P., Kawamura, T. & Hasegawa, T., 2004, '*Web service gateway - A step forward to e-business'*, Proceedings of the IEEE International Conference on Web Services (ICWS'04).
24. Napster, http://www.napster.com/ntg.html
25. Parameswaran, M., Susarla, A. & Whinston, A. B., 2001, *'P2P networking: An information-sharing alternative'*, http://crec.mccombs.utexas.edu/works/articles.
26. Roure, D. D., Baker, M. A., Jennings, N. R. & Shadbolt, N. R., 2003, 'The evolution of the grid', in Berman, F., Hey, A. & Fox, G. (eds.), '*Grid Computing - Making the Global Infrastructure a Reality'*, John Wiley & Sons, Ltd.
27. Roy, J. & Ramanujan, A., 2001, 'Understanding web services', *IT Professional*, vol. 3, no. 6, pp. 69-73.
28. Samtani, G. & Sadhwani, D., 2002, 'Web services and peer-to-peer computing', *Web services Architect*. http://www.webservicesarchitect.com/content/
29. Schneider, J., 2001, '*Convergence of peer and web services'*, Available: [http://www.openp2p.com/lpt/a/1047] (Oct 6, 2004).
30. Toh, C. K., 2001, '*Ad hoc mobile wireless networks: Protocols and systems'*, Prentice Hall PTR.
31. Tomoya, K. & Shigeki, Y., 2003, '*Application of P2P (peer-to-peer) technology to marketing*', Proceedings of the 2003 International Conference on Cyberworlds (CW'03), pp. 1-9.
32. Tsaparas, P., 2004, '*P2P search'*, Available: [www.cs.unibo.it/biss2004/slides/tsaparas-myP2P.pdf] (3/10/, 2004).
33. *Universal Description, Discovery, and Integration (UDDI)* 2000, Available: [http://publib.boulder.ibm.com/infocenter/wsphelp/index.jsp?topic=/com.ibm.etools.webservice.consumption.doc/concepts/cuddi.htm] (Sep 10, 2004).
34. W3C. Web Services Architecture Requirements Oct 2002, http://www.w3.org/TR/wsa-reqs.
35. Weisman, C., 2002, '*The essential guide to RF and wireless'*, 2nd ed, Prentice Hall PTR.
36. *What is ad-hoc network* (2003), Available: [http://whatis.techtarget.com/definition/0,289893,sid9_gci213462,00.html] (7/10/2004).
37. Xiao Feng, J., Junhua, X., Hua, Z. & Zuzhao, L., 2003, '*A realizable intelligent agent model applied in dynamic e-business*'. Proceed**ings of the** IRI 2003. IEEE International Conference on Information Reuse and Integration, http://ieeexplore.ieee.org/xpl
38. European Commission, 2006 '*Innovation ecosystems – A specific roadmap*', DG Information Society and Media.
39. Denning, P.J. & Metcalfe, R.M., 1998, '*Beyond calculation: The next fifty years of computing'*, (edited) Springer, ISBN: 0387985883
40. European Commission, 2006 '*Technologies for digital ecosystems – Innovation ecosystem initiative*', available at http://www.digital–ecosystems.org
41. Quinton, S. (2005). *The Learning Preferences of Current Generational Groups*. Fourth International Conference on Science, Mathematics and Technology Education Victoria, Canada. August 25-28, 2005.
42. Williams, R., & Dreher, H. (2004). Automatically Grading Essays with Markit© ; Proceedings of Informing Science 2004 Conference, Rockhampton, Queensland, Australia, June 25-28, 2004