Introducing 'Meta-Network': A New Concept in Network Technology

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Abstract— A well-designed computer network technology produces benefits on several fields within the organization, between the organizations(sub-organizations) or among different organizations(sub-organizations). Network technology streamlines business processes, decision process. Graphs are useful data structures capable of efficiently representing a variety of networks in the various fields. Metagraph is a like graph theoretic construct introduced recently by Basu and Blanning in which there is set to set mapping in place of node to node as in a conventional graph structure. Metagraph is thus a new type of data structure occupying its popularity among the computer scientists very fast. Every graph is special case of Metagraph. In this paper the authors introduce the notion of Meta-Networking as a new network technological representation, which is having all the capabilities of crisp network as well as few additional capabilities. It is expected that the notion of meta-networking will have huge applications in due course. This paper will play the role of introducing this new concept to the network technologists and scientists.

Index Terms— Co-input, Co-output, Generating Set, Invertex, Metagraph, Meta-Networking, Outvertex.

I. INTRODUCTION

A Computer network is an interconnected collection of devices that enables you to store, retrieve, and share information. Commonly connected devices include personal computers (PCs), minicomputers, mainframe computers, terminals, workstations, thin clients, printers, fax machines, pagers, and various data-storage devices. Recently, other types of devices have become network connectable, including interactive televisions, videophones, handheld devices, and navigational and environmental control systems. Eventually, networked devices everywhere will provide two-way access to a vast array of resources on a global computer network through the largest network of all, the Internet.In today's business world a computer network is more than a collection of interconnected devices. For many businesses the computer network is the resource that enables them to gather, analyze, organize, and disseminate information that is essential to their profitability. The rise of intranets and extranets—business networks based on Internet technology—are an indication of the critical importance of computer networking to businesses. Intranets, extranets, and the Internet will be treated in more detail in a later section. Most businesses have installed intranets to collect, manage, and disseminate information more quickly and easily than ever before. They established intranets simply to remain competitive; now, the momentum continues, and extending the company network to the Internet is the next technological transformation of the traditional business. Computer networking is that you can store virtually any kind of information at, and retrieve it from, a central location on the network as well as access it from any connected computer. We can store, retrieve, and modify textual information such as letters and contracts, audio information such as voice messages, and visual images such as facsimiles, photographs, medical x-rays, and even video segments[1].

Networks also make holding meetings more efficient. For example, collaboration software can search through a number of busy schedules to find time for a meeting—including the schedules of employees at different locations. The meeting can be held over the network through a teleconferencing session, thus eliminating the travel cost for those employees at remote sites. The attendees can simultaneously view and edit the same document and instantaneously view each other's changes as they are made.

A networking solution that enables data and resource sharing between different types or brands of hardware, operating systems, and communication protocols—an open networking environment—adds another dimension to the information-sharing capabilities inherent in computer networking. Open networking products enable you to work on the type of computer best suited to your job requirements without encountering compatibility problems. They also allow you to choose the system that best works in your environment without sacrificing interoperability with other companies' systems [2].

Networks speed the flow and analysis of data so that businesses can determine which products their customers want most at each of their physical stores.

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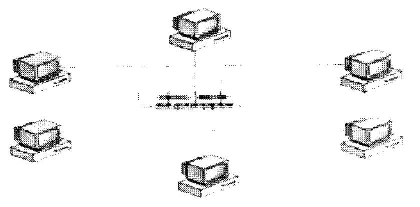

Figure-1 Computer Network

II. GRAPH AS A COMPUTER NETWORK

Graph provides a powerful tool to model objects and relationships among objects. The study of graph begins by the famous Konigsberg bridge problem originated by Euler in 18th century. The graphs can be used to model problems in many areas such as transportation, scheduling, networking, robotics, VLSI, mathematical biology and Software engineering, to list a few only out of many. A number of optimization problems from these areas can be phrased in graph -theoretic terms [2].

A graph or undirected graph G is an ordered pair G: = (V, E) where V is a set, whose elements are called vertices or nodes, E is a set of edges or lines. In the directed graph the direction of connection is also given.

Graph can be used to model the networks, where the various model sites and edges model links between sites. Each edge has the direction of flow of data; it may be bidirectional or unidirectional.In Figure-2, A Graph (in the form of computer network) is shown.

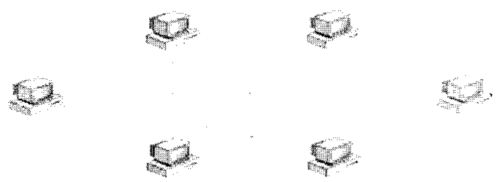

Figure-2 Graph as a computer network

III. METAGRAPH

In 1992 in the classical papers ([4],[5]), Basu and Blanning introduced the concept of metagraphs as an extended concept of the crisp graphs. In this section we reproduce the preliminaries about the new data structure 'metagraph'. First of all we visit a digraph and a hypergraph and see their drawbacks; and then we see how the metagraphs can overcome these drawbacks.

Example 3.1 Consider a system in which (i) there are three input variables:-
Pri = the sale price of a product,
Vol = the sales volume,
Wage = the prevailing wage rate,
(ii) and there are two intermediate variables:-
Rev = the revenue realized, which depends on price and the volume.
Exp = the expense incurred, which depends on the volume sold and the wage rate.
(iii) and there are two output variables:
Prof = the realized profit,
Notes = notes payable as a result of borrowing to cover expense.

We assume that Pri and Vol determine Rev, Vol and Wage determine Exp, and Rev and Exp determine Prof and Notes. Notes can be determined either from Rev and Exp (along with Prof) or directly from Exp. Thus there is limited amount of redundancy and inconsistency. A digraph (directed graph) of above said problem is shown in Figure-3 below :-

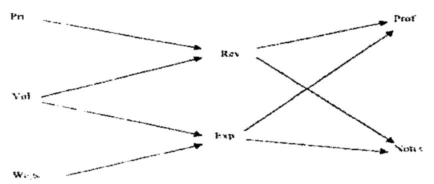

Figure-3 A digraph

In a hypergraph each edge is a set of one or more elements, which allows us to represent relationships among multiple elements ([6][7][8][9]). We see in Figure-3 that Price, Volume, and Revenue are all part of a single relationship. As before we can identify paths consisting of sequences of hyper graph edges connecting variables such as Price and Profit. The hypergraph [8] does not tell us whether Price and Volume are used to determine Revenue or whether some other relationship is intended. But the recent concept of metagraphs introduced by Basu & Blanning ([4],[5]) could be regarded as a breakthrough as this can be completely modeled by a metagraph in which Price and volume are the member of same set, volume and Wage are also the member of same set, Rev and Exp have some common features but they are the member of same set as shown below :-

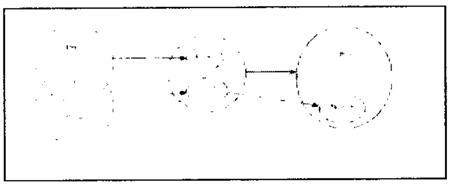

Figure-4 Meta graph

The above metagraph with its Co-input and Co-output invertices and outvertices can be represented as follows.

$E = \{(\{Pri, Vol\}, \{Rev\}), (\{Vol, Wage\}, \{Exp\}), (\{Rev, Exp\}, \{Prof, Notes\}), (\{Exp\}, \{Notes\})\}$,
$Invertex((\{Rev, Exp\}, \{Prof, Notes\})) = \{Rev, Exp\}$,
$Outvertex((\{Rev, Exp\}, \{Prof, Notes\})) = \{Prof, Notes\}$,
$Coinput(Rev, (\{Rev, Exp\}, \{Prof, Notes\})) = \{Exp\}$,
$Cooutput(Prof, (\{Rev, Exp\}, \{Prof, Notes\})) = \{Notes\}$.

To be precisely acquainted with the concept of metagraphs, one requires to know the following terminologies.

Definition 3.1. Generating set

The generating set of a metagraph is the set of elements $X = \{x_1, x_2 \ldots x_n\}$, which represent variables of interest

Definition 3. 2. Edge

An edge e in a metagraph is a pair $e = \langle Ve, We \rangle \in E$ (where E is the set of edges) consisting of an invertex $V_e \subseteq X$ and an outvertex $W_e \subseteq X$, each of which is a set and may contain any number of elements. The different elements in the invertex (outvertex) are co-inputs (co-outputs) of each other.

Example 3.1 A metagraph can be understood by the following example: S = < X, E >, is a metagraph when

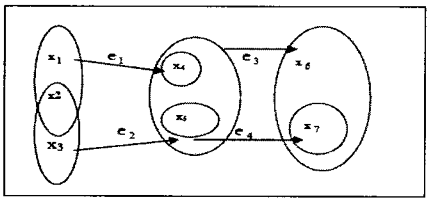

Figure-5 A metagraph

$X = \{x_1, x_2, x_3, x_4, x_5, x_6, x_7\}$ is the generating set, and $E = \{e_1, e_2, e_3, e_4\}$ is the set of edges. The edge set can be Specified as

$E = \{\langle \{x_1, x_2\},\{x_4\} \rangle, \langle \{x_2,x_3\},\{x_5\} \rangle, \langle \{x_4, x_5\}, \{x_6, x_7\} \rangle, \langle \{x_5\}, \{x_7\} \rangle \}$

In-vertex is a function having one argument which can find out the internal vertices from a given set.

In-vertex $(\langle \{x_4, x_5\}, \{x_6, x_7\} \rangle) = \{x_4, x_5\}$.

Out-vertex is another function having one argument which can find out what are the out vertices from the given set.

Out-vertex $(\langle \{x_4, x_5\}, \{x_6, x_7\} \rangle) = \{x_6, x_7\}$.

Two more functions of metagraph are the co-input and co-output functions each have two arguments. Co-input function gives he co-input from a given set.

Co-input $\{x_4, \langle \{x_4, x_5\}, \{x_6, x_7\} \rangle \} = \{x_5\}$.

Co-output $\{x_6, \langle \{x_4, x_5\},\{x_6, x_7\} \rangle \} = \{x_7\}$.

Generally the edges of the metagraph are labeled as

$e_1 = \langle \{x_1, x_2\}, \{x_4\} \rangle$,
$e_2 = \langle \{x_2, x_3\}, \{x_5\} \rangle$,
$e_3 = \langle \{x_4, x_5\}, \{x_6, x_7\} \rangle$,
$e_4 = \langle \{x_5\}, \{x_7\} \rangle$.

Definition 3.3 Metagraph

Metagraph $S = \langle X, E \rangle$ is a graphical representation consisting of two tuples X and E. X is its generating sets and E is the set of edges defined on generating sets. The generating set X of the metagraph S i.e. the set of elements $X = \{x_1, x_2 \ldots x_n\}$ represents variables.

A simple path h(x, y) from an element x of the generating set to an element y of the generating set is a sequence of edges $\langle e_1,e_2,\ldots\ldots\ldots e_n \rangle$ such that

(i) $x \in$ invertex(e_1),
(ii) $y \in$ outvertex (e_n), and
(iii) for all e_i, ($i = 1 \ldots n-1$) outvertex (e_i) $\cap$ invertex (e_{i+1}) $\neq \phi$.

The Co-input of x in the path (denoted Co-input(x)) is the set of all other invertex elements in the path's edges that are not also in the outvertex of any edges in the path, and the

Co-output of y (denoted Co-output(y)) is the set of all outvertex elements other than y. The length of a simple path is the number of edges in the path.

IV META-NETWORK: A NEW NETWORK MODEL

In this section, we introduce the notion of meta-network.

Definition 4.1 Meta-network

Meta-network is analogous to network of objects in which there is set (of objects) to set (of objects) mapping in place of node (object) to node (object) as in a conventional network structure.

In meta-network of computers, this set have same type of computers or an intranet connected to some another set or another intranet. The set to set mapping in a meta-network is shown below by an example.

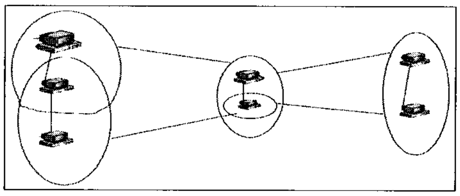

Figure-6 A Meta-Network

A meta-network may be fully or partially connected.

Homogeneous or fully connected Meta-Network

Homogeneous or fully connected Meta-Network preferred model for describing computer viruses and worms. Homogeneous Meta-Networks offer significant advantages. First, analytical mathematical models can be easily applied to them; second, they provide a good abstraction of very large networks when the majority of the susceptible hosts are accessible from an infectious agent and third, performing simulations. Homogeneous Meta-Networks can be built in Figure-7

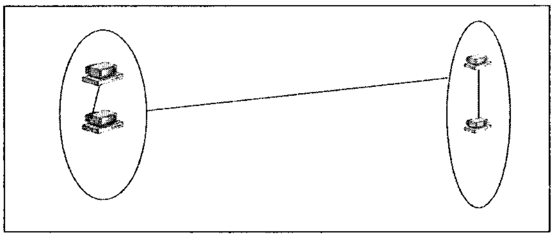

Figure-7 Homogeneous or fully connected Meta-Network

Partially connected Meta-Network

Partially connected Meta-Network provides a good approximation to very large networks such as the Internet. The connectivity of the Internet, along with that of many other technical and social networks enable us to combine the power and capabilities of diverse equipments and to provide a collaborative medium to combine the skills of different people having the same interest are also member of same sets. Meta-networking also make the traditional business process more efficient and more manageable. An example of partially connected Meta-Network is shown in Figure-6

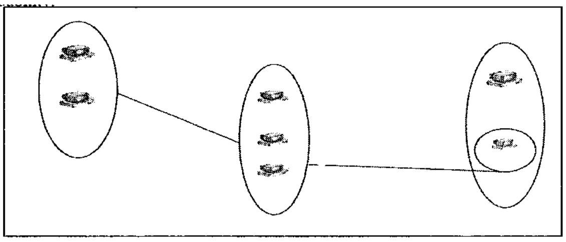

Figure- 8 Partially connected Meta-Network

V. OPERATIONS ON META-NETS

If M1 and M2 are two Meta-Networks, then the following operations can be applied as mentioned below:

(1) Union M1 ⋃ M2

(2) Intersection M1 ⋂ M2

Definition Union M1 ⋃ M2 The union of two Meta-Networks M1 and M2 is the union of its set of elements or objects as well as the union of its connection or transitions i.e. mapping from one object to another.

Definition 5.1 Intersection M1 ⋂ M2

The intersection of two Meta-Networks M1 and M2 is the intersection of its set of elements or objects as well as the intersection of its connection or transitions i.e. mapping from one object to another.

Suppose we have Meta-Networks M1 and M2 as follows.

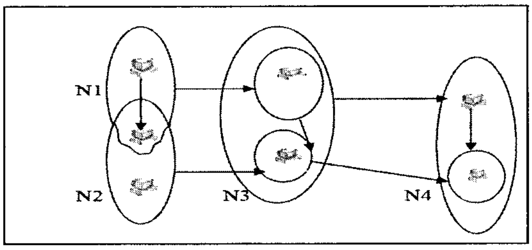

Figure-9 Meta-Network M1

Here N1, N2, N3, N4 are the node set of the network M1

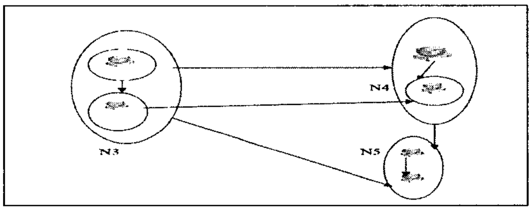

Figure-10 Meta-Network M2

Here N3, N4, N5 are the node set of the network M2

The union of the above Meta-Networks will be as follows.

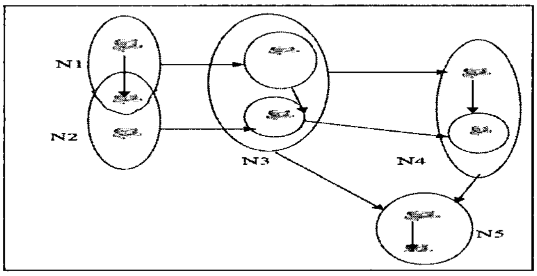

Figure-11 M1 ⋃ M2

Here N1, N2, N3, N4, N5 are the node set of the Network M1 ⋃ M2

The intersection of two Meta-Networks M1 , M2 will be as follows

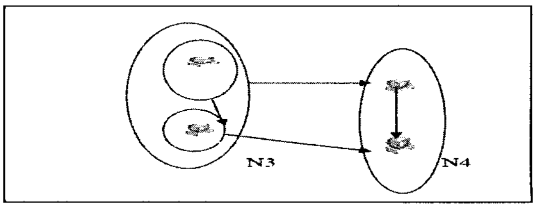

Figure-12 Meta-Network M1 ⋂ M2

Here N3, N5 are the node set of the network $M1 \cap M2$
Similarly set-algebra commutative laws can `also be analogous mentioned below:

(1) $M1 \cup M2 = M2 \cup M1$,
(2) $M1 \cap M2 = M2 \cap M1$,
(3) $M1 \oplus M2 = M2 \oplus M1$
(4) $M1 \cup \phi = M1$
(5) $M1 \cap \phi = \phi$
(6) $M1 \oplus \phi = S$,
(7) $\phi \cup \phi = \phi, \phi \cap \phi = \phi$

Meta-Network follows all set algebraic laws.

VI. CONCLUSION

In this paper we have presented Meta-Networking a new design concept in the field of network technology. Meta-Networking is a network of computer model having links between the various computers in the given network. It has all the features of graphical network as well as few extended features of set theory also. This paper is just an introductory one, and the authors at present are on rigorous work to unearth its various properties, various operations on meta-nets with its application domains especially for data mining, web mining and in decision theory.

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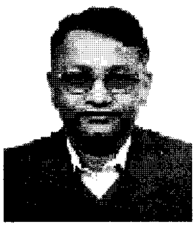

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