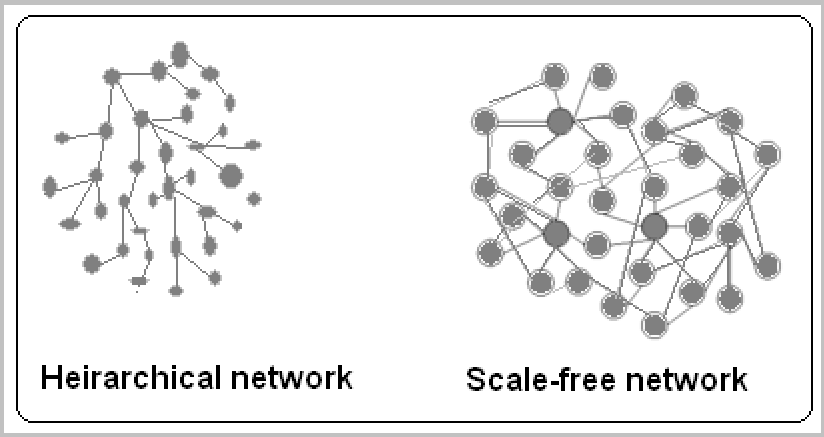
appeared oln 9th Feb 2009

Networking is the name of the game

Interconnectedness is both good and bad, says S.Ananthanarayanan.

The most interconnected networks are the most efficient and also the most stable. But they can also be the most vulnerable and also limited as they grow larger. And then, there are two kinds of networks, the hierarchical and the scale free, the latter being more interconnected.



A good example of a vast, ***scale free*** network is the Internet. It provides so many alternate paths to navigate that it can swiftly remedy traffic snarls and would need a ***major*** catastrophe for it to come down! Social networks and the network of blood vessels that a living organism develops are other examples, the second also being ***hierarchical***. As to the vulnerability of these networks, instances may be how fast a virus spreads through the Internet, AIDS in a community or the way snake venom or how quickly injected drugs spread through the body.

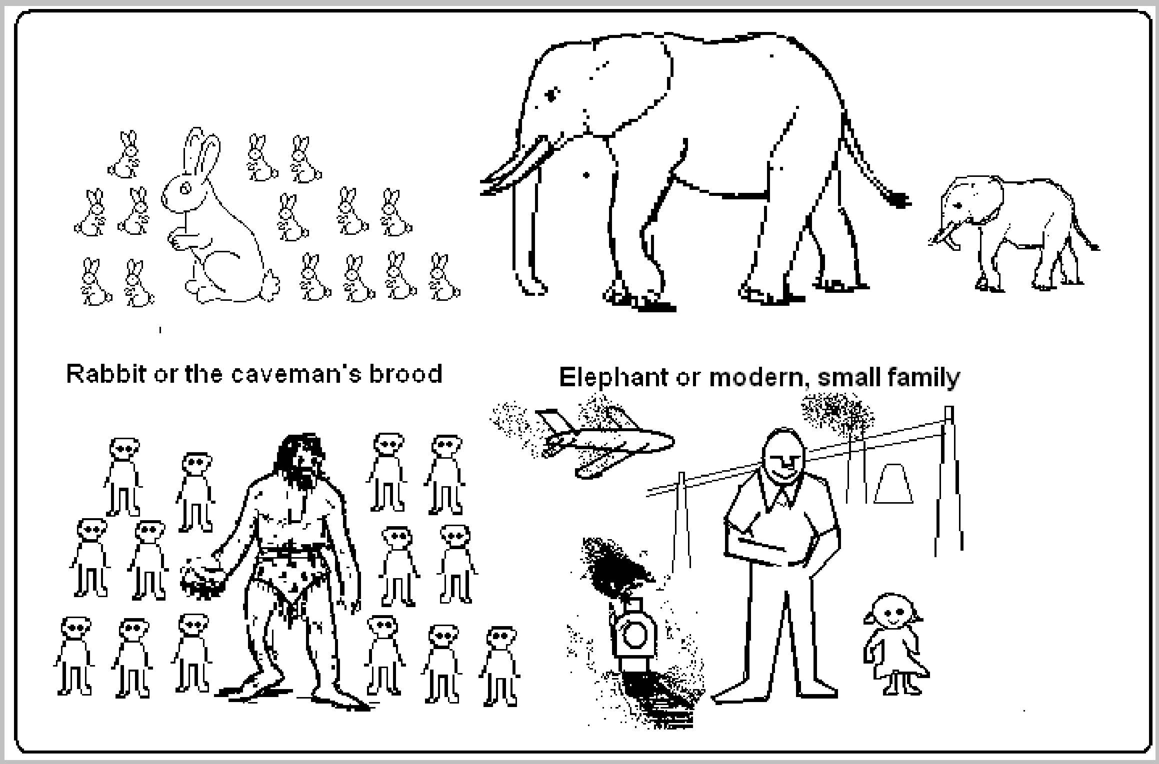
The energy network

Another organic network that has grown enormously in recent times is the interconnectedness of trade and energy use in the world. We have seen the mobile phone revolution take over the earth in just a few years. And, as for energy use, the network of roads, railways, shipping lines, pipelines, transmission lines, and communications has made energy stored in one part of the world freely available everywhere - and to this, maybe not to this alone, we may attribute the crisis of global warming that has overtaken the world in just a few decades.

In trade, also, transport and communications have eliminated distance and enabled the so called efficiency of syndicated use of resource to mobilize massive, cross border investment. Trade has been the handmaiden of energy use and has taken financial levels to dizzy heights that are similar to the volume of energy flows. And the failure of governments to appreciate the effects of energy on global warming or the failure of financial institutions to foresee the present trade crisis are because the networks that drive both these processes have not been understood.

Size matters

The scalability of a system is how efficiently it performs if it is made more powerful or extensive – like whether the structure of an office LAN can work for the Internet or a local sales model can work for international sales. Biologists and mathematicians have examined the structure and behaviour of networks and one of the areas of study was the way many features of plants and animals depend on their mass. It has been observed that the metabolic rate, or how fast an animal uses energy, is proportionate to its mass raised to the power of ¾ (which is less than 1). In other words, if a fish weighing 1 kg uses a certain amount of food in a day, a fish that weighs 100 kg would not use 100 times as much energy, but only about 31 times as much. This rule, which is known as ***Kleiber's Law***, is found to be correct over a wide range, from very small to very large animals.



The explanation is found to be largely because of the geometry of the vascular system of animals and the greater costs to deliver nutrients at the extremes of a large body. Larger animals thus have less structural mass and more reserve mass, leading to what amounts to less vitality, mass for mass. An elephant would grow, breathe and reproduce more slowly, and live longer, than a mouse, and a mouse than an ant, and so on.

The explanation may not be very exact, but the idea is that larger networks are less efficient and process energy more slowly than smaller networks – and this is true for all kinds of networks, organic, social or technological.

Implications

In an issue of the journal, ***Nature*** earlier this month, Melanie Moses of the Department of Computer Science at the University of New Mexico writes that this theory, known as the ***Metabolic Theory of Ecology*** (MTE) explains the observation that the fertility rate declines with the economic success of a community. The human body uses energy from food only at the rate of a 100 watt light bulb. But the rest of the energy that a typical North American uses is 100 times more and all this energy comes largely from burning fossil fuels, and delivered through widespread and expensive infrastructure networks.

That people with the most resources should have the least offspring runs counter to Darwin’s prediction that population should increase geometrically. This is especially so because the even the greater life expectancy due to prosperity does not explain the drop in fertility. But the drop does fit the increased energy use, according to MTE. Another way of expressing the phenomenon is that the North American consumes energy like a 10,000 kg animal, but also reproduces only at the rate of such a beast!

Moses explains that just as an elephant may take longer to acquire the resources to reproduce, the modern American, who invests a constant fraction of available resources in each child, may take longer to acquire that fraction in a wealthy society. Similarly, the plenty in so many other ways in modern society comes at a cost that gets disproportionately high. The higher investment in education in different communities is correlated with falling birth rates. Even in China, where birth rate has been controlled by the government, the success of the program has been side by side with massive increase in per capita energy consumption.

“Global agricultural production increased six-fold from 1900 to 2000 by increasing energetic investment in agriculture 80-fold. This appalling return on investment in the energy used to fertilize, harvest and transport food means that we now put more energy into acquiring food than we obtain from eating it”, Melanie Moses says.

“In the decades ahead, we need to understand how social and infrastructure networks constrain individual behaviour, and structure cities and societies in ways that increase innovation inducing interactions but reduce transport and travel distances. By doing so, we’ll stand a better chance of meeting the needs of a large, voracious and growing human population without decimating the resources available to future generations”, Melanie says.