A Discussion of "Smart Grid Biology"

** Transcript from the keynote address given by Clement Chen, SVP Strategic Development, Science Applications International Corporation (SAIC) at the McMaster University Smart Metering and AMI Conference in Burlington Ontario on November 30, 2009*

Good afternoon folks. It's good to be here with you. I guess length of introduction is inversely proportional to what value-added I'm going to give you (laughter). Actually, I have no charts or notes today, so you'll be spared. My reward for that is they're going to record this discussion, so now I'm actually going to have to be accountable for what I'm saying, which is dangerous to say the least.

Before I start, I had a late evening dinner last night with a colleague of mine. The subject of the rock group U2 came up. Bill Wong, my colleague...where are you Bill? Are you here? He's probably the only person on earth who's never heard of U2. (You've been working too hard, Bill – you ought to take some vacation!) By the way, are there any U2 fans here? I see a few. Did any of you go to the U2 360 concert here in Toronto? One person…and you're afraid to admit it…that's okay. My older son thinks U2 is the world's loudest folk band.

If you can get past the egomaniacal persona of Bono, and focus on what U2's really all about, you'll find that what really makes the magic of U2 is their guitarist, the Edge. Particularly, the way he plays his guitar and how his use of the delay function or an echo feature makes a richness of sound that is somewhat transcending. Are there any guitar players in the audience today? Just a few. Have you ever tried to figure out how to replicate the Edge sound? It sounds really simple, but it's incredibly intricate. Just to give you a sense of how a lot of us have too much time on our hands, a couple of us have actually performed an analysis on this, and figured out that if you take the delays per minute that he uses when he hits a chord and it echoes and divide it by the beats per minute, the number is 2.718281828459045. It's "e"…Euhler's number. Simply, perhaps arguably, the most important number in all of mathematics. What's interesting about this is that when you're playing the guitar, when you're teetering on the edge of "e", your guitar playing borders on almost going chaotic. But then you hit the "e" function, and the sound becomes self-replicating, self-propagating. Why am I talking about this? Smart Grid is really going to be the intersection point of many different disciplines. And what is going to be key in a lot of it is pattern recognition born out of inter-disciplinary insight, and being able to apply it in a bunch of different areas that historically have not been users of that insight.

When we talk about Smart Grid, all the discussion so far… you know, smart metering, AMI, demand response, grid optimisation, sensors, automation, distributed generation, renewable integration…in the future PHEV integration, and so on and so forth, that's all well and fine. But the underlying important thing that's happening is ubiquitous connectivity with two-way flow of information and power. For those of you who sat in on the end-user break-out session, Tim Wolf of R.W. Beck, an SAIC company, alluded to this as well. Ubiquitous connectivity - when things become ubiquitously connected, really weird things begin to happen. And these weird things point to an environment that increasingly becomes biological in its characterisation. It starts to take on performance and behaviours more indicative of living pathways than linear systems. So, in order to actually have a sense of where this is going to go, we need to revisit and tear apart what this ubiquitously connected environment is all about…and in order to do that you have to talk about the network metaphor. By the way, I was asked to basically give you all a lot of food for thought, so I'm coming at this from out of left field. The whole idea is to stimulate thinking.

If you talk about the network metaphor, you have to go back to processing power, bandwidth, connectivity and storage. Processing power is probably the most prominent. You can't pick up any trade magazine without reading about Moore's Law. And everybody knows what that is. Processing power doubles every 18 months. It's actually been a design goal that's been achieved, for a period of 40 to 50 years. Processing power doubles every 18 months…a function of how many transistors you can cram onto a sliver of silicon, how quickly you can shrink it, so on and so forth.

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But think about this; if processing power is doubling every 18 months, all else being equal, what's happening to the price? It's getting halved every 18 months. And it gets halved again. And it gets halved again. It effectively approaches a functional price point of zero, the dollar per function that is. It's not that the absolute price is zero…just to give you an example…a thousand dollars of computing today is greater than a thousand dollars of computing ten years ago by a factor of a thousand…that's what we're talking about here. So you're sitting there saying, "Well geez, how did the semi-conductor industry survive when they were facing price deflation of 40% to 50% a year?"

Just to give you a sense of this…if you're selling something for a dollar today, next year you have to sell the same thing for 50 cents. The year after, 25 cents, the year after 12 cents, the year after 6 cents…how do you even begin to make the economics close on a dynamic that has that sort of characteristic? The answer is…volume.

Unbelievably, or believably, depending on what your perspective is, the semi-conductor industry over the last many decades, undergoing 40 to 50% annual price deflation, has actually grown 15 to 18% compound annual growth rate every single year during that same duration…because they're punching out these chips, these jelly beans, all over the place. What is not as well known is that for every chip that is sitting in one of these work-stations, there are hundreds if not thousands of chips that are sitting in a toy, a greeting card, a shirt, a shoe, a toilet, a cell phone, a wall or what have you.

What happens when you start connecting all these jelly beans? The jelly beans don't necessarily have to be smart. They just have to be able to ingest and excrete information…two-way flow. Kevin Kelly, the executive editor of Wired magazine, has said that "dumb parts properly connected, yield smart results." It's kind of like how SAIC works (laughter) but the smart results is debatable…(laughter)….I'm just kidding…ooh, I forgot this thing is being recorded…..(laughter)…My last day's Friday!....umm…but seriously…when you start connecting these things, the environment morphs.

But there's another dynamic that I want you to focus on, and it's the notion of doubling. We talked about processing power doubling every 18 months. If you double something, and then double it and double it, after a while, the characteristic of that doubling starts to take on a very weird behavioural dynamic. It starts to become biological. It hits a knee in the curve, and crazy things start to happen. Let me tell you a vignette that most of you have probably heard before, but it's worth relaying again, because it viscerally captures and gives you a sense of what happens when things double. It's a vignette that Ray Kurzweil wrote about in "The Age of Spiritual Machines" probably 10 years ago. It's about the inventor of chess and the Chinese emperor. How many people have heard of this before? …. Nobody?... okay, well,…I won't have to apologise for being redundant. The story goes…there's the inventor of chess who came up with this game, and the Chinese emperor was so elated about this game that he called the inventor in and said, "…because this game has given me such joy, I'm going to give you anything you want in my kingdom." The inventor asks for only one thing: one grain of rice on the first square of that chess board. But the caveat is he wants that grain of rice to double through the 64 squares of that chess board. Chinese emperors aren't mathematicians. He said, "you GOT it!" Well, if the emperor actually did the math, he would realise that the only thing the inventor asked for was 18 million trillion grains of rice…at a density of 10 rice grains per square inch, that's enough rice to cover the entire surface of the Earth, two times over, oceans included…….That's a lot of rice…….

Chinese emperors don't like to be wrong, so the emperor called the inventor back in once it became obvious what the request was. And the emperor said to the inventor, "Guess what? We're going to have you executed!!..." So the moral of the story is…no one likes a smart ass! (laughter) No, the real moral of the story is this – while in the first half of that chess board, through the 32nd doubling or so, you're talking about a couple of billion grains of rice…probably covers a couple of acres on the emperor's property…the inventor is probably making a gajillion dollars on the commodities trading exchange, but the inventor should be rewarded for industriousness. No big deal. You get to the second half of that chess board…every successive doubling becomes greater than the entire history of earth up until then…and then it doubled again…and then it doubled again. The monstrosity of the request doesn’t become evident until the second half of that chess board.

Kurzweil calculates that the second half of the chess board, in processing power, occurred in the mid-90s. Interestingly enough, that roughly coincides with the uptake after the inflection point of the invention of Mosaic in which the internet basically became democratised for the masses. And now you have the commercial internet, which is, in many people’s minds, the most successful commercial invention of all time. I can safely say that the inventors of the ARPANET, which was really the precursor to the internet and was designed to be a command and control infrastructure for defence purposes in case of nuclear detonation…they did not envision you and I selling our Pez dispensers on eBay on the internet today. That was not in the design specs. So when Myles D’Arcey (of Hydro One) this morning as well as many of the successive speakers talk about how “we’re not really sure entirely where this thing is going”…that humility is very wise. If anyone thinks that they’ve got it wired and they’re mapping out the timeline of when this-is-going-to-happen and when that-is-going-to-happen, you can guarantee that that’s exactly what’s not going to happen.

The power of doubling - interestingly enough, you hear about Moore’s Law all day long…processing power…and that is the least relevant aspect of commercial computing. Because all the while as this was going on, bandwidth and connectivity enabled by that bandwidth was tripling every 12 months…storage also was increasing at a rate 50% faster than processing power… but you never heard about that. What does this mean? There’s a notion called “differential deltas” - differential growth rates. If something doubles every year versus something that doubles every 2 years, what do you have after 5 years? The thing that doubles every year is up over 30 some odd X while the thing that doubles every 2 years is up 5-6 X…something along those lines. So basically, what you have is a 2X differential in growth rate over a 5 year period that translates into a 5-6-7X differential and it keeps exploding into infinity. The significance of that differential isn’t evident initially.

One thing we have to remember is that linear and exponential growth rates, in the near term, look the same. It’s very hard to tease it out. And then the thing that’s growing exponentially hits a knee in the curve and explodes to infinity, and you’re left wondering “what happened?!”

Technology in many places right now is expanding exponentially, but we experience it linearly. This leads people to make two mistakes: they overstate what’s going to happen in the near-term because they don’t understand the dynamic, and, perhaps more frighteningly, they grossly underestimate what happens in the long-term. So, just to give you a sense of how this differential growth rate has expressed itself, think about the canonical assumption of all commercial information and communications technology - the assumption was that the ones and zeros flying around inside this computer was greater than the ones and zeros coming into and out of it. This is what made us highly tolerant of what Scott McNealy used to call “those hairball applications” coming out of Redmond, Washington, otherwise known as Microsoft. You put up with all that bloat ware and all that nonsense because you could not count on a network connection. You had to be self-sustaining as a lone wolf.

Now what’s happening? The ones and zeros inside the computer are not only, on a relative basis, moving slower than the ones and zeros coming into and out of it, but the differential growth rates that I just got finished talking to you about are diverging to infinity.

What does that mean? That means that the computer, as a unit of measure, is no longer relevant. It has become disaggregated… and is becoming re-aggregated…across the network. Therefore, the network IS the computer…Bill Joy WAS right…he was just 25 years too early. But it’s happening now. I know there are a lot of skeptics in the audience sometimes when I talk and they kind of say, “ahh, I don’t believe that.” Well, if you don’t believe me, think about this - whenever you’re on travel…if you can’t get a network connection for your laptop…if your cell phone doesn’t work… if your Blackberry doesn’t work…you are functionally useless. (…..you may have been useless before, but now you’re REALLY useless!! (laughter))

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The implication of all of this is the following - no single node is now self-defining. And that node…whether it's you…whether it's a utility…whether it's another Fortune 500 company…whether it's the government…whether it's a province, state, or local municipality…no single node is now singularly defining. In fact, the value that you deliver is a function of network externalities… this is what this entire environment is pushing towards. And there are a whole bunch of other aspects of networks that I could talk about later if you're interested…but I am under time constraints…someone can give me the hook if I'm running out of time.

…So you're probably wondering, why go on and on about this whole network thing…this doubling thing and what-have-you… how does this relate to Smart Grid? Well, let's talk about Smart Grid. Let's talk about Smart Grid doubling.

Smart meters…there were about 1.3 million smart meters in North America in 2006. By 2012, estimates are that number is going to be well over 30 million. You're talking about a 20X expansion in 5 to 6 years' time. That is, unless the world ends in 2012 (laughter), but who cares about that? You won't care anyway! (laughter)

Smart meters…and the meter is just a gateway into an explosion of data, so the exponential growth function of the data severely dwarfs that of the meter.

Global storage…that thing's growing at a 40-45% compound annual growth rate, which basically translates into doubling every 18 months…just like Moore's Law. Granted…it's coming from a small starting point…not including pumped hydro. I'm talking about sodium sulphur, lithium ion…all the other distributed storage assets that are going to be coming into play. Storage is a very interesting wild-card factor because it is a system resource. It is, by definition, a network externality right from the get-go by virtue of exactly what it is. It will be a very interesting tool for creating, what in the financial world would be called "synthetic stocks." You can potentially create a portfolio of energy assets that has a certain volatility profile that you can potentially try to manage to deal with intermittency, dump energy, and everything else.

Global solar PV…probably the fastest growing renewable source of generation out there…again, a lot of small starting numbers… but it's growing at a 35% compound growth rate a year… probably doubling every 20-24 months.

Look at wind. It's been growing at a 28% compound growth rate for the last TEN YEARS…and then again, when we talk about differential growth rates, it'll get fractal… I'll talk more about that in a few minutes.

What is generally true is sometimes specifically false. With wind, I'm talking about a general 28% compound annual growth rate… on a global basis. Look at China. China is the giant sucking sound in the east. And it's going to impact a lot of things. Wind installed capacity in China has doubled every single year for the last 4 years. They have come from virtually nowhere to be the number 4 player in wind in the world and growing.

Demand response…some are projecting that it's going to quadruple in the next 5 years. It's essentially a fifth fuel for virtual peak power. It's a very interesting phenomenon that's on a growth curve not unlike Solar PV.

PHEVs…again, another thing that no one is sure of how this thing's going to play out…but basically, PHEV's are going to go from a standing start to having a million and a half to two million units fielded by the year 2015. Think about the growth rate that goes from zero to a million and a half to two million in just a couple of years…

These are all biological growth rates folks…and they portend of a very interesting dynamic…which many of us are not sure what that's going to be.

Amidst all this, what IS NOT doubling every 14-18 months…or what isn't growing much at all…or what is actually shrinking? This, perhaps, can give you a window into what may be happening in the future. Transmission infrastructure has been potentially bled out for many decades. Compare transmission infrastructure against all the doublings and doublings and doublings going on in all of the other elements that we've been discussing…it perhaps can give us a window into what's going to happen.

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Central generation…coal, nuclear, or otherwise……hasn't been growing much or is perhaps going in the opposite direction. What does this point to in broad strokes? Perhaps the single, biggest change is in the entire architectural underpinning – not unlike what happened in commercial information technology – this change is waiting in the wings for energy and the electric power grid. The move from centralisation to decentralisation is huge. It doesn't happen overnight. In fact, the way it expresses itself is oftentimes…like that pond…with the lily pads. If those lily pads are doubling every day…and it's been doing that all summer long…you probably didn't notice that pond with all those lily pads until the very last week, if not the very last few days. Because, if it's been doubling every day…the day before it was only half full…the day before it was only a quarter full…the day before it was only an eighth full. So the thing was growing imperceptibly all summer long, and you didn't notice it until the very last week. And by then there's nothing you can do about it. When you look at things like solar PV and the distributed constructs that it will enable, don't lose sight of that…because significance far precedes momentum in this environment.

…and with this distributed infrastructure comes a whole bunch of other concepts that are normal for biological systems…and, frankly, quite scary and abnormal for the world in which we've lived in for a long time in the electro-mechanical age. Let's talk about some of these factors.

At the core of biological systems becomes this question of control…control versus adaptability. The two tend to trade off against each other. In biological systems, sometimes you see this thing called "meta-control." It's the control of control. It's about the lever you can pull over there that actually works through this amazing web of horizontal causality to create effects over here. And meta-control isn't about directly coupling one knob you can turn here for one unit of output over there. It's not a one-to-one thing. To give you a sense of meta-control… let's look at genes. Most genes don't code for themselves. They activate…deactivate…turn on…turn off a whole laterally connected series of other genes. To put it in a more tangible way…look at SAIC…we have 45,000 employees, over 80% of which are engineers and scientists. While there are only 5,000 of us actually doing the work, the other 40,000 are sitting around telling us what to do (laughter)…you know this is true…this is how it works in almost all organisations.

Meta control…distributed control…intelligence without centrality is the core of what biological systems are about. How do you achieve that? Perhaps, maybe reflexes and not thinking is the way to think about it. When a batter is in the batter's box staring at a 98 mph fastball coming towards the plate…his eyes are telling him one thing…his ears…his hearing is telling him something else…his skin sensitivity, feeling the air changing is telling him something else. How does he actually resolve these sometimes conflicting signals in an instant? Is there a master controller station up here doing range and speed calculations and all this other stuff and the guy then hits a home run? No. They're just not resolved. The outcome just becomes the result of a clash of reflexes, and once a success is developed, pattern recognition occurs and is then propagated for the next time they see it. That's kind of how it works…so we think.

Lateral causality…this is a really interesting phenomenon. Think in child terms… children play rock, paper and scissors…the rock beats the scissor, the scissor beats the paper, and the paper beats the rock…I want to make sure I get this right because I always lose this game to my 8 year old. Everything is both cause and effect.

The equivalent age old question that academics like to toy around with is, "what is the colour of a chameleon when it stands in front of a mirror?" Does the chameleon cycle through a bunch of different colours and eventually settle out at some level? Does the chameleon change colours forever? Does the chameleon just retain the colour that it had when it first looked into the mirror? What is the answer?

What's more important than the answer is the fact that that lizard and the glass now become "one" system…and it has to be engineered and thought about as a single system. When you we talk of AMI…think of the consumer as the lizard…not literally (laughter). But AMI is almost like the beginnings of a mirror that you're putting in front of the lizard consumer…how will the consumer behave? And that consumer behaviour takes place not in 400…500…1,000…10,000 person increments…but I'm talking millions. Large numbers behave differently than small numbers. I think some of the initial work that Dean Mountain (from McMaster University) is working on with regard to consumer behaviour is spot on. The consumer part of the equation…the psychology of human behaviour in large numbers…can not be discounted and is perhaps the single most important aspect of the entire equation against which the technology challenges actually look small.

Lateral causality…there's also this thing known as a subsumption architecture. It's a system of systems but the systems that we're talking about aren't, frankly, just technical…the communications, the sensors, and everything else. They also include the regulatory…the economic…the consumer behavioural patterns…they are all going to be primary here.

…and lastly, the topic of fractals. Fractals are basically self-similarity at multiple hierarchical levels that occur during phase transitions or percolation periods – that kind of thing. If you think about how biological systems work, they tend to work with small systems that do some function somewhere in a self-sustaining way that gradually becomes annexed within a larger picture. This portends of very interesting things in the area of micro grids, for example, or perhaps even what Hydro One is doing with their living lab in Owen Sound. The thing about ecosystems is that you can't touch any part of an ecosystem without it touching everything else. You cannot statically optimize any element in the equation without impacting some other element in that equation. You have to have the entire equation in view somehow at the outset…perhaps, the right way to do that is through a micro version of the thing and then letting it "fractalise" upwards…because that's how a biological system works…through chunking of control from the bottom-up. It's not about some central brain deciding for everyone how it's going to work. That's exactly how it doesn't work.

The last thing I'm going to say is this…and I'll leave you, again, with another thought piece to consider. Stephen J. Gould was the late paleontologist from Harvard. He once posed what he called "the most excellent question." I always love this about academicians…"the most excellent question"….very modest! His most excellent question was this: "what good is 5% of an eye?" Most of us, without giving that question much thought, will sit there in a linear way of thinking and say "Gee, that's not very excellent at all…because I'd rather have 5% vision than none." Just like having 50% is better than 40%...40% is better than 30%...30% is better than 20%.......

What is so excellent about that question? Well the reason why that question is excellent is because 5% of an eye does not equate to 5% vision. You need 100% of an eye to even have the possibility of having 1% vision…because the rods and cones…the lenses…and everything else…the physicality…the physiology of the eye isn't even the beginning of the system known as "vision." The eye, indeed, almost has to become part brain. It's as much an information and cognitive process as it is the physicality of visioning. That metaphor is directly applicable to Smart Grid. Smart Grid is not a power systems problem. It's not a physical…physiology…physicality problem. And it is not an IT problem. It's a system-of-systems problem and must be viewed as such. Ultimately, Smart Grid is, potentially, going to be the central nervous system of the 21st Century transformation of not only the electric power system…but all of energy.

That's all I have folks. I'm out of time…..thank you. (34:46)