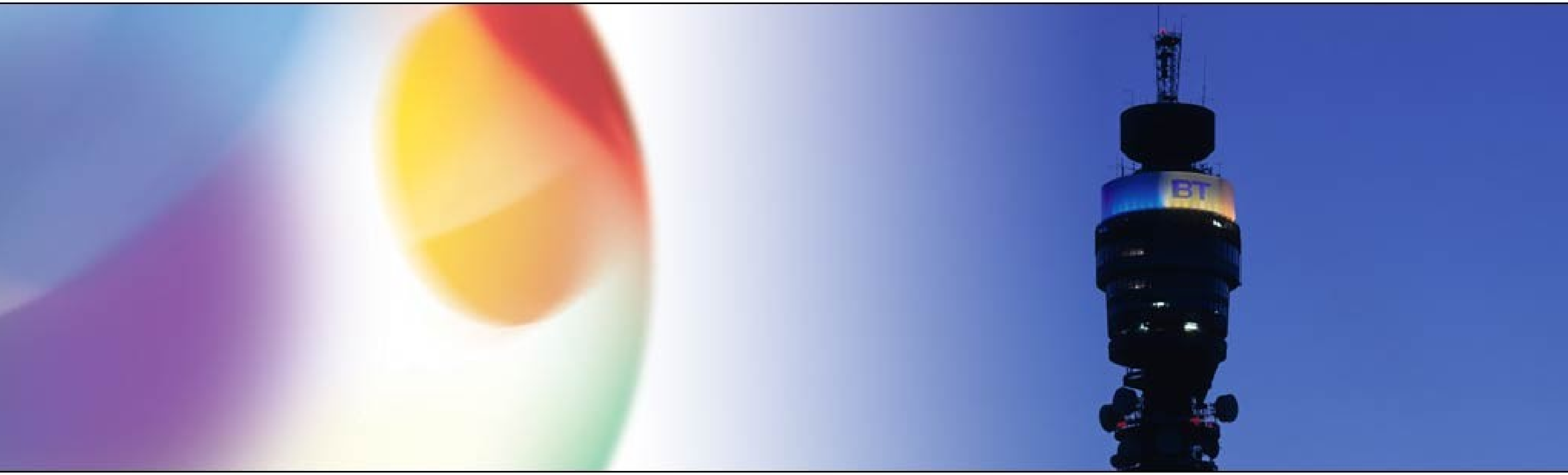

Towards Energy-Aware Self-* Services

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“Green is the new black...”

True ☐

False ☐

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True ☐

False ☑

The “Green” agenda is here to stay

- It is not a fad
- It is definitely not a “green wash”
- It is not even “just” a corporate social responsibility issue...
- It is a good old fashioned resource optimisation problem with an environmental twist
- In short: a reliable supply of (relatively) cheap energy can no longer be taken for granted
  - Some experts argue that “easy” oil has already peaked
  - As with any other finite resource approaching scarcity, fossil fuel prices will only be going up (statistically)
  - Carbon taxation (or some other scheme designed to discourage waste) is probably next

The impact on ICT

- This trend will affect every sector, including ours...
- Reminder: the global carbon footprint of ICT (understand: its fossil fuel needs) is estimated to be equivalent to that of the air travel industry
- In India, black-outs due to a mismatch between electricity supply and demand are already the norm rather than the exception
- Serious ICT infrastructure is plugged into backup generators to prevent service interruption
- As fuel prices rise, this kind of makeshift solution becomes increasingly uneconomical

Solutions so far

- Substantial progress has been made through improving energy efficiency of data-centres
- But we're running out of such “easy wins” to keep the necessary momentum
- Furthermore, driving down overall energy consumption is only part of the answer
- Building data-centres in places where needs are consistently low (fresh air cooling) and/or cheap energy is consistently available (e.g. near a waterfall) offers useful complementary options
- But critically (for this community) all these approaches only require limited self-* capabilities (e.g. “conventional” autonomics)

Service migration

- Instead of moving the hosting environment, we can move (some of) the hosted applications
- This is of course nothing new: centrally orchestrated service migration in response to predictable variations has been around for a while
- Assuming that electricity prices mirror demand patterns (e.g. day-rate versus night-rate) and knowing the cost incurred through the migration itself (service interruption, data transfer etc.), designing a set of energy-aware migration policies is relatively straightforward

But...

- What of unforeseeable fluctuations like those resulting from incorporating renewable sources into the power supply?
- What of applications with “fuzzy” boundaries (e.g. peer-to-peer) and no designated “orchestrator”?
- What of “service ecosystems” in which commonality of goal between mutually dependent applications can be a transient phenomenon?
- This is arguably where Self-Adaptive and Self-Organizing properties (i.e. those leading to desirable emergent behaviour) can make a difference...

Collective decision-making

- We consider the case of a complex service comprised of autonomous modules in need of a common hosting environment. Such a service would have to be be capable of:
  - Identifying a hosting site of relatively high value when available options vary in quality
  - Reaching agreement within a large population of units so as to avoid scattering between sites (even when quality is homogeneous)
  - Minimising the number of “trial-and-error” relocations during migration
  - Maintaining flexibility in such a way that changing conditions in the environment only initiate a new migration when the potential benefits outweigh the cost of relocation

The Model

- Two categories of modules
  - "Scouts" explore the hosting environment and "compare notes"
  - "Workers" encapsulate real services and interact with scouts for decision-making purposes
- When probing a new host *y* (probability P_{exp}), a scout *A(x)* will change preference, which we denote $A(x \rightarrow y)$, with probability:

$$P = \frac{Q_y^\eta}{Q_x^\eta + Q_y^\eta}$$

Interaction rules

- Scout *A(x)* meets scout *B(x)*: both units are scouts and they share the same favourite hosting site *x*. In this case, the rule is $l_A \leftarrow l_A+1$ and $l_B \leftarrow l_B+1$ (mutual reinforcement).
- Scout *A(x)* meets worker *B(x)*. In this case, $l_B \leftarrow l_B+1$ and if $l_B = l^*$, *B* moves to *x*.
- Scout *A(x)* meets scout *B(y)*. In this case, a random test is performed to determine the winner and loser of the “conflict”. *A* is the winner with probability:

$$P = \frac{Q_x^{\lambda} l_A^{\gamma}}{Q_x^{\lambda} l_A^{\gamma} + Q_y^{\lambda} l_B^{\gamma}}$$

Interaction rules (cont'd)

- After the test has determined which scout managed to convince the other to change preferences, $I_{winner} \leftarrow I_{winner}+1$ and $I_{loser} \leftarrow 0$. If A is the winner, then $B(y \rightarrow x)$, otherwise $A(x \rightarrow y)$
- Scout $A(x)$ meets worker $B(y)$. In this case, $I_B \leftarrow 0$ and $B(y \rightarrow x)$, which simply indicates that workers are “followers” of scouts and don’t “question” their recommendations

Proof-of-Concept demonstration