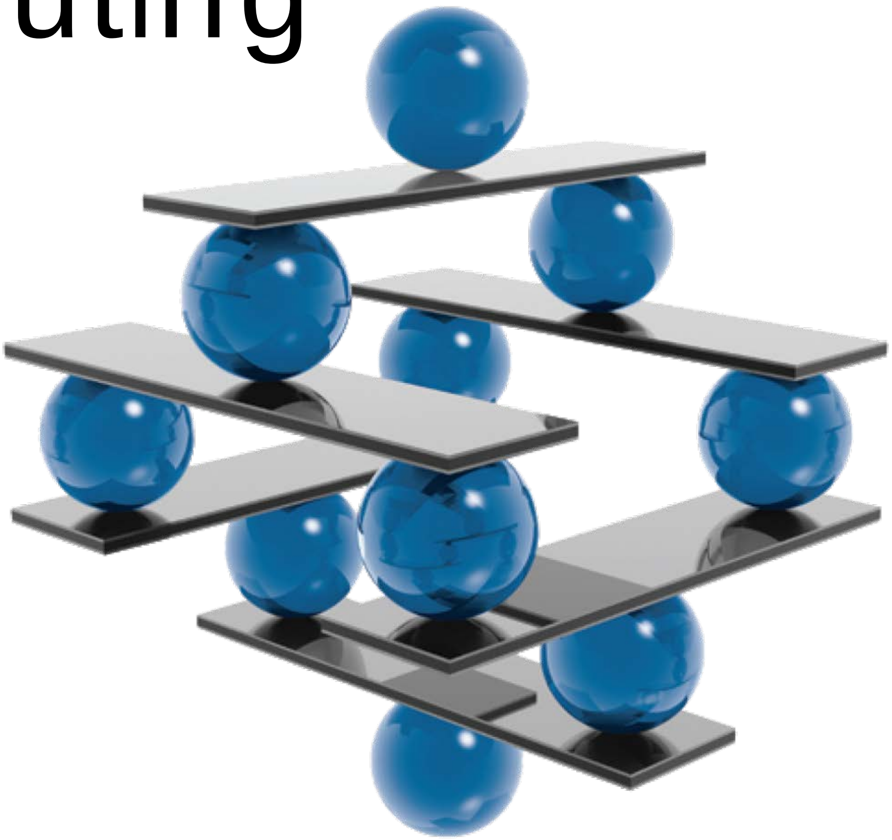
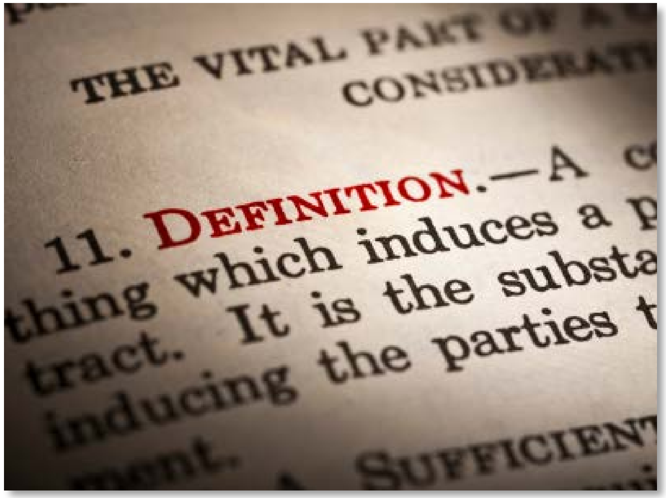
Peer-to-Peer and Cloud Computing



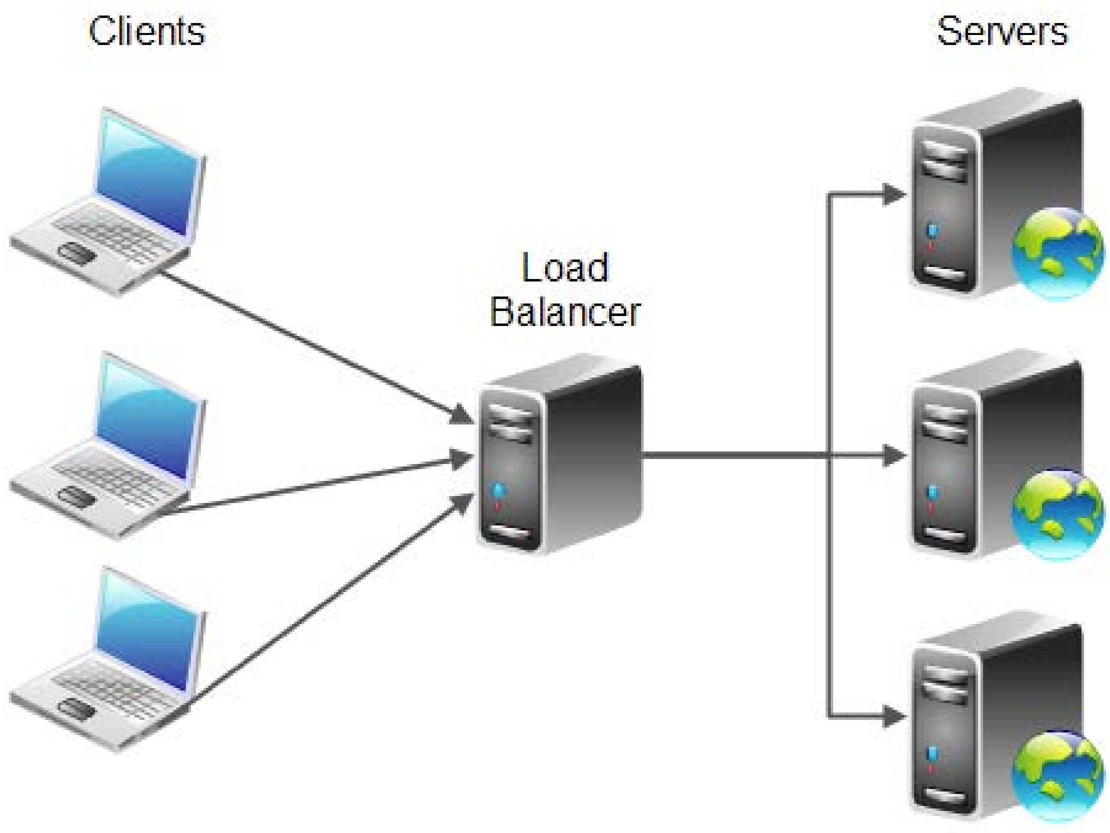
Load Balancing Concepts

1. Introduction
2. Naive Approaches in a Nutshell
3. Honey Bee-inspired Load Balancing
4. Summary



What is Load Balancing?

- Distribution of **workload** (tasks, requests, jobs) among available **resources** (i.e. servers, allocation-units).
- Resolve imbalance: equally **distribute** load among available resources.
- User/Client is re-directed to a server that is currently capable of serving his **request.**
- User/Client does not notice re-direction and thinks that he is communicating with one single server throughout the entire session.


Clients
Load
Balancer
Servers

Why do we need Load Balancing?

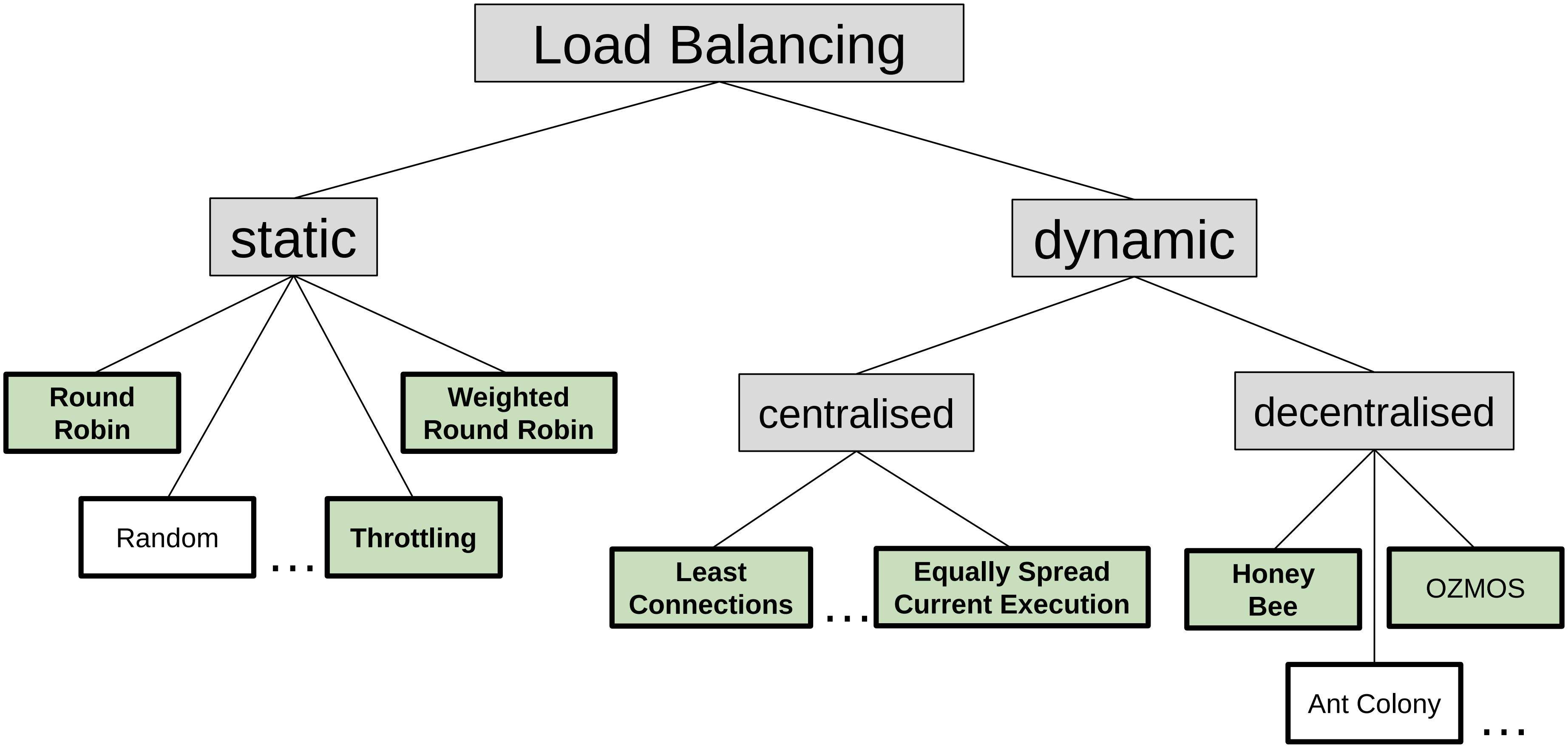
- **Quality of service**: e.g. availability, reliability, robustness, performance
- **No SPoF**: load will be assigned to alternative servers in advance
- **Cost efficiency**: avoidance of idling servers (in contrast to one or more overloaded servers)
- **Faster response:** increased overall throughput (think of user-experience)
- **Flexibility**: new hardware can be added easily

Challenges

- **Uncertainty**: amount of incoming tasks (e.g. HTTP-requests)
- Heterogeneous resources/servers
  - Varying performance and capabilities of servers
  - Different classes of tasks: not every server is capable of serving any request
- Scalability of the distributed systems (Grids, Clouds, P2P) must not be limited, e.g. by an overloaded central Load Balancer → SPoF

- Not any of the existing approaches meet the requirements resulting from the challenges mentioned above.
- Some of them are of static nature → do not consider the current situation in terms of actual workload.
- **Dynamic** and **decentralised** approaches have been investigated and are still topics of current research.

Classification of Load Balancing Algorithms



* We will have a look at the highlighted ones

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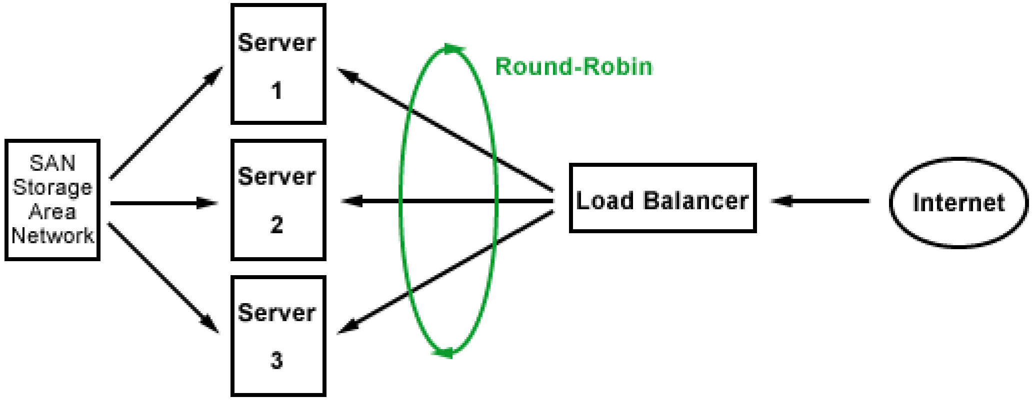
Static Approach: Simple Throttling

- **Servers** are assigned a limit/threshold for a maximal accepted load
  - Number of active connections
  - Number of processing requests
  - etc.
- **Load Balancer** maintains a list of all available allocations units (i.e. servers) and their current state.
- New request
  - Load Balancer traverses list
  - Selects first server whose threshold has not exceeded.
- Request is assigned to that allocation unit.

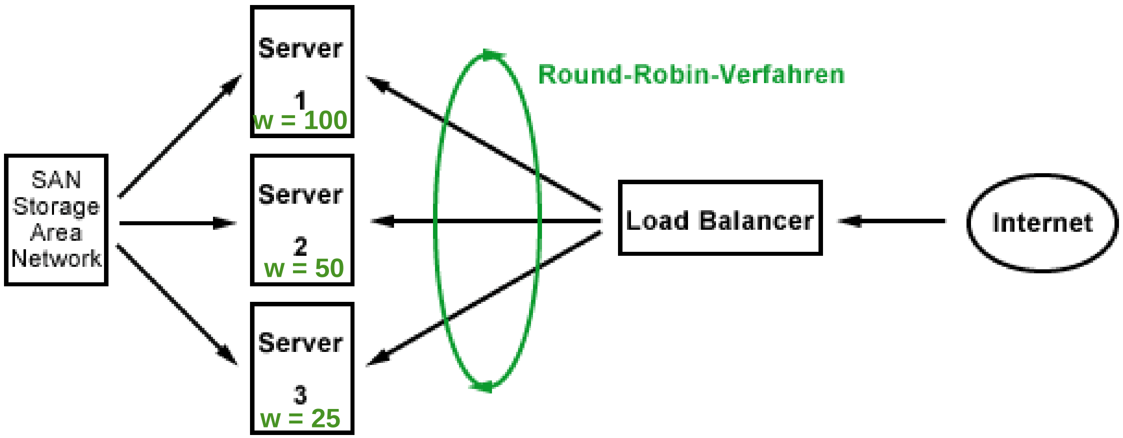
- Sequential distribution of incoming requests among available servers
- Sequence is **fixed** and **not dependent on the current load** of the incorporated servers →static
- Servers should all provide **identical** (web) services and be equipped with **equal** computational capacity
- Under this precondition, **round robin** is a simple and effective method for balancing load originating from incoming requests



Source: Elektronik Kompendium

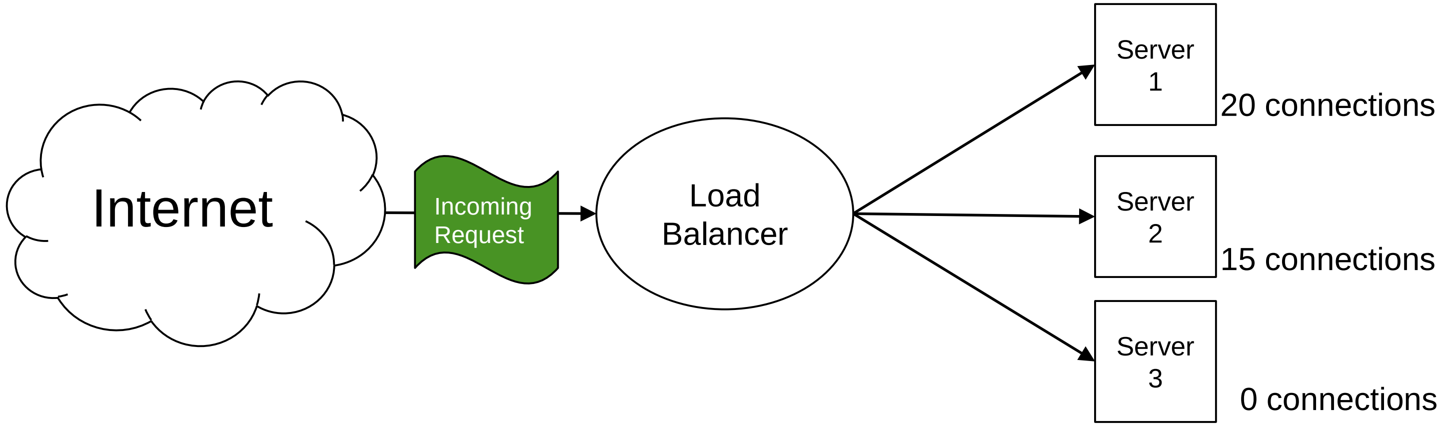
Static Approach: Weighted Round Robin

- Overcomes the drawback of the conventional approach.
- Useful if the servers do not all have the same capacity.
- Administrator can **pre-assign the capacity** of available servers in terms of a **weighting**, i.e. the server with the highest weight is the most efficient one.
- Thus, Server 1 always is assigned two consecutive requests before Server 2 gets his first one for instance.



Source: Elektronik Kompendium

- Considers the amount of currently **active connections** on each participating server.
- An incoming request is scheduled to the server with the smallest number of active connections.
- **Same preconditions** as for the Round Robin approach should be met for this method.



Dynamic centralised approach: Equally Spread Current Execution

- **Avoid load imbalance** among the available servers
- Requests are migrated to other servers with less workload.
- Incoming requests are **queued** and spread around all available servers to achieve a **nearly equal load** among all allocation units.

- Imaginable drawbacks
  - **Migration costs** for re-allocating requests from one server to another.
  - **Complex requests** (e.g. time-consuming computations on the server-side): migration might be difficult or not possible at all due to interrupting and purging at the old location as well as setting up at the new location.

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Motivation

- Server farms, or rather **Internet-server colonies** may co-host multiple web services
- Customers purchase **resources** offered by providers of such Internet-server colonies
- Problems
  - limited **number of available servers**
  - **unpredictable amount of HTTP requests** to reach the hosted web-services
- **Optimised server allocation policy** is a challenging task from the provider‘s point of view

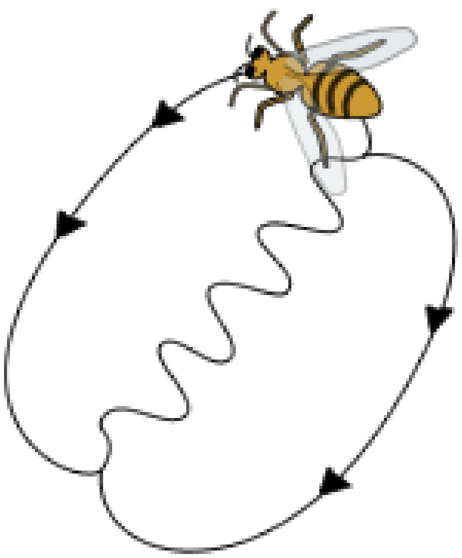
Goal: Maximise provider‘s **revenue** and satisfy customer‘s **demand** by allocating available resources efficiently

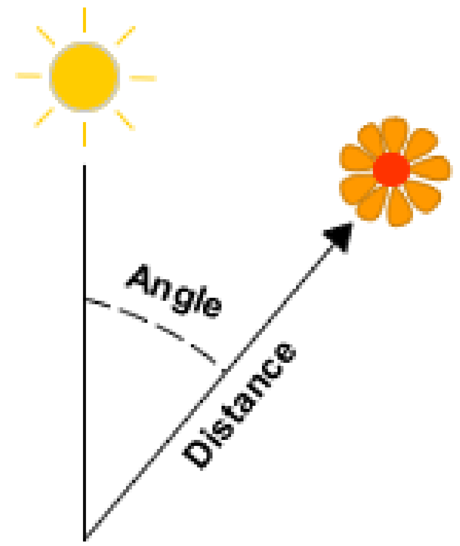
- Nature-inspired approaches
- Swarm intelligence definition:
  – *Collective execution of primitive interactions amongst individuals (viewed at the microscopic abstraction level), leads to a complex global (macroscopic) behaviour that could not be accomplished by any single member of the group/system.*
- Swarm intelligence can be characterised by
  1) Self-Organisation → decentralised and unsupervised
  2) Adaptiveness → dynamically varying environment
  3) Robustness → Accomplishing global goal even in the presence of faulty acting individuals
- Examples: Ants, bees, termites, wasps

Honey Bees Collecting Food/Nectar (1)

- Scenario of swarm intelligence observed from honey bee colonies
- **Forager bees:** dynamically allocated in a self-organised manner to collect nectar from food sources
- Allocation with regard to the **profitability** of the food sources (nectar quality, distance to hive,…)
- Forager bees provide **feedback** regarding the profitability of the visited food sources
- Additionally: *scout bees* **explore** for new flower patches
- Feedback mechanism is called *waggle-dance*

Waggle dance





- The length of the waggle-dance is composed of two factors:
  1) A *response threshold* determined by the current nectar flow into the hive (known from interaction with receiver bees)
  2) A *profitability rating* of the advertised flower (a function of nectar-quality, -bounty and distance to the hive)
- Inactive forager bees observe a waggle-dance and decide whether to follow the dancer to the advertised flower patch or not
- Observing foragers do <u>not</u> acquire global knowledge by means of observing every waggle dance, but rather select a certain waggle-dance randomly

- Analogy from nature: Allocate *forager bees* among food sources (flower patches)

Bee colony	Server colony
Forage site (flower patch)	Service/Request queue
Flower patch volatility	unpredictable HTTP request
Forager bee	single server / allocation unit
Forager group collecting from one source	Virtual server serving specific HTTP request / service queue
Bee colony	ensemble of servers
Forager round trip time	time cost
Nectar quality	value-per-request-served

Remember: Co-hosting of several web services

- Model
  - M groups of n servers called *virtual servers* $VS_j, \quad j = 0, \dots, M-1$
  - M *service queues* Q_j facing certain type of HTTP request
  - Server $s_i \in VS_j$ serving Q_j is paid c_j cents per served request

- Honey Bee-inspired server allocation
  - $s_i \in VS_i$ posts advert with duration $D = c_j \cdot A$ with probability p after it has finished serving the last request
  - A denotes an *advert scaling factor* → constant
  - Any server s is either a *forager* s^f or a *scout* s^s

After specific time interval T_i.

- Honey Bee-inspired server allocation (continued)
  - If server is forager s_i^f it reads an advert randomly with probability r_i
  - If server is scout s_i^s it selects a virtual server $VS_j, j = 0, \dots, M-1$ randomly
  - A server s_i determines its profitability by comparing its own *profit rate* P_i with the *overall profit rate* of the colony P_{colony} (by means of a Lookup-Table, see below)
    - $P_i = \frac{c_j R_i}{T_i}$, where R_i denotes the number of requests served by s_i and T_i is a certain time interval
    - $P_{colony} = \frac{1}{T\_colony} \sum_0^{(M-1)} c_j R_j$, where R_j denotes the total number of requests served by VS_j and T_{colony} again is a given time interval

Profit Rate	P[Reading] r_i
$P_i \leq 0.5 P_{colony}$	0.60
$0.5 P_{colony} < P_i \leq 0.85 P_{colony}$	0.20
$0.85 P_{colony} < P_i \leq 1.15 P_{colony}$	0.02
$1.15 P_{colony} < P_i$	0.00

<< Lookup Table for dynamic assignment of r_i

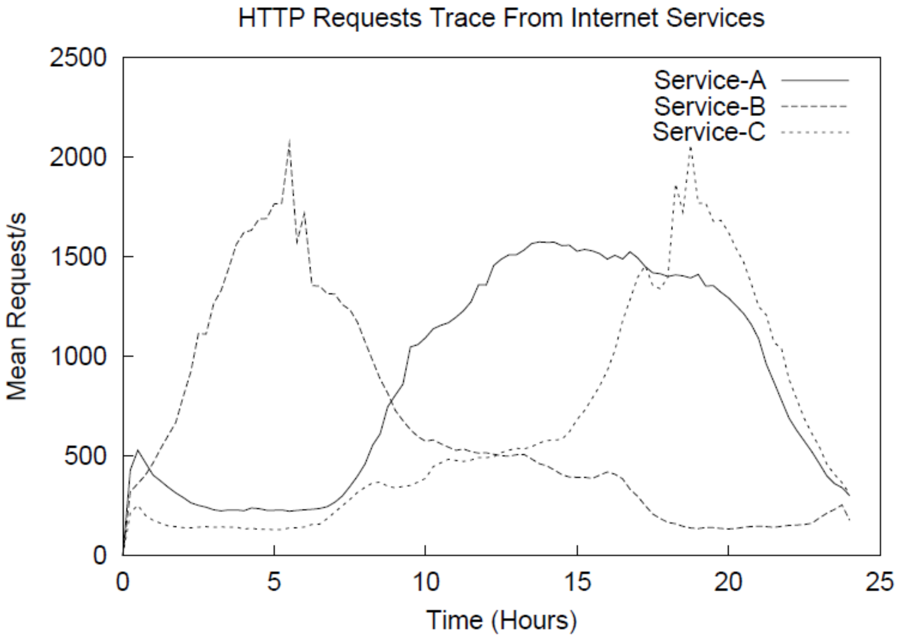
[NaTo03]

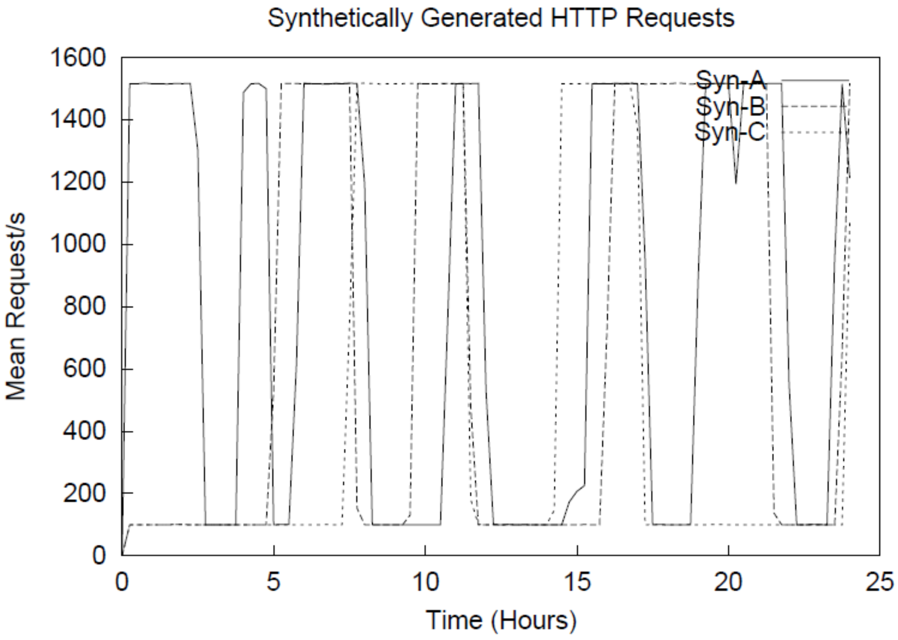
- Honey Bee-inspired server allocation (continued)
  - Resulting effect: a server is more likely to read an advert (observe a waggle dance) when it serves a low-profit queue Q_j
  - Approach resembles the behaviour of real honey bee colonies
  - with the difference that here a server may skip reading an advert $(r_i = 0)$,
  - whereas in real bee colonies the foragers decide to dance or not
  - depending on global knowledge regarding the hive‘s *nectar-intake-rate* and the time until a receiver bee is available (response threshold).
- Aims in maximising the provider‘s revenue rather than minimizing the load of particular servers.
- With slight modifications for the profit rate definition P_{colony} the latter objective should be easily accomplishable.

Evaluation Scenario

- Comparing performance of honey-bee algorithm with three benchmark algorithms: *Omniscient*, *Greedy* and *Optimal-Static* configuration
- **Real HTTP-request traces** from a commercial service provider as well as synthetic traces following an inhomogeneous Poisson process come into operation
- Experiments conducted for Internet Server Colony with **2 and 3 virtual servers** (i.e. different web-services)
- Virtual servers are composed from a total of **50 physical servers**
- Performance metric: **Total revenue** earned by the entire server colony

HTTP-request arrival patterns





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Load Balancing based on Honey Bee Allocation: Evaluation (2)

- **Omniscient**
  - **Upper bound** on possible profitability
  - Informationally impossible and computationally prohibitive in practise
  - Computed by means of dynamic programming (**complete knowledge** required)

- **Greedy**
  - Standard **heuristical** approach
  - „What would have been optimal during the preceding time period“
  - Reallocate servers based on the optimal profit that could have been achieved given the HTTP-arrival pattern from the **past time-interva**l

- **Optimal-static** (server re-allocation takes place only seldom)
  - Using the best from among all static (fixed) allocations
  - Many SLA providers do not change their allocations more than once a month
  - Choose the best out of **k possible server allocations** for a time-horizon split into N discrete time-steps

- Experimental results for synthetically generated HTTP-requests

Revenue ($) for synthetically generated HTTP requests		
Algorithm	**2-VS**	**3-VS**
Omniscient	970.636	1.119.400
Honey Bee	868.949	1.003.050
Greedy	836.077	968.087
Optimal-Static	810.510	860.363

[NaTo03]

- Honey Bee algorithm shows good adaptability to varying HTTP-request arrival patterns
- However, for a low variability Greedy approach outperforms Honey Bee algorithm by approx. 1.2 %

Revenue-per-served-request: c_j = 0.5 cent
Simulation duration: 24 h period

- Experimental results for real internet service provider traces

Revenue ($) from real Internet service traces		
Algorithm	**2-VS**	**3-VS**
Omniscient	1.066.440	1.336.960
Honey Bee	1.050.110	1.238.470
Greedy	1.043.400	818.040
Optimal-Static	844.822	1.108.360

[NaTo03]

- Honey Bee algorithm again outperforms Greedy and Optimal-Static approach and performs within 1.55% (for 2-VS) respectively 7.95% (for 3-VS) of the Omniscient

Revenue-per-served-request: c_j = 0.5 cent
Simulation duration: 24 h period

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Summary

- A brief overview of **Load Balancing strategies** was presented
- Some simple and basic approaches were sketched.
- Additionally, a **self-organised and nature-inspired** method was discussed in more detail.
- Provide a basic understanding of the **necessity** of Load Balancing and an insight how this important challenge can be achieved.
- Load Balancing is a broad research field that could easily fill a designated lecture considering the underlying network technologies and specific implementations in more detail.

Literature

[NaTo03] Sunil Nakrani and Craig Tovey. 2003. On Honey Bees and Dynamic Server Allocation in an Internet Server Colony. To appear in *Proc. 2nd International Workshop on the Mathematics and Algorithms of Social Insects*, Atlanta, Georgia, USA. December 15-17, 2003

[NaTo04] Sunil Nakrani and Craig Tovey. 2004. On Honey Bees and Dynamic Server Allocation in Internet Hosting Centers. *Adaptive Behavior - Animals, Animats, Software Agents, Robots, Adaptive Systems* 12, 3-4 (September 2004), 223-240.

Load balancing figure taken from

http://tutorials.jenkov.com/software-architecture/load-balancing.html