44. ITG Workshop der Fachgruppe 5.2.4 am
15.11.2013 an der TU München

Dynamic Virtual Network Embedding (Re-Embedding)

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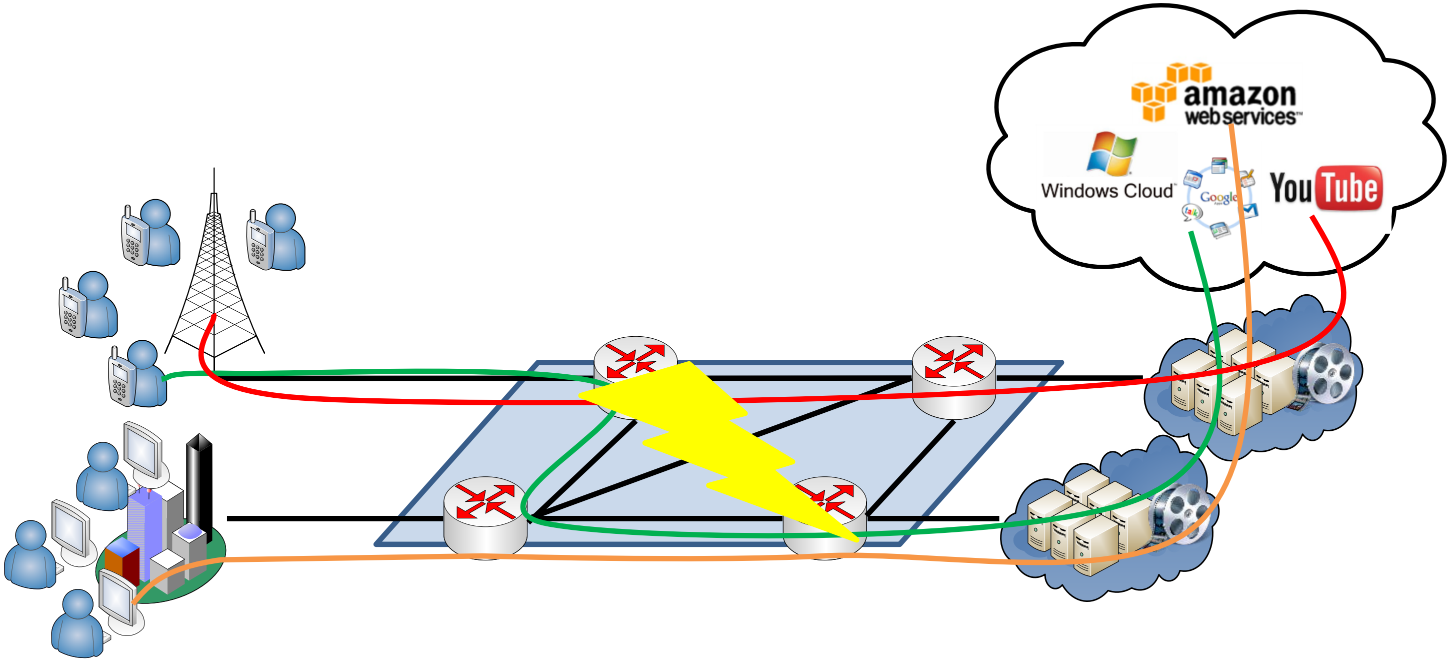
Motivation

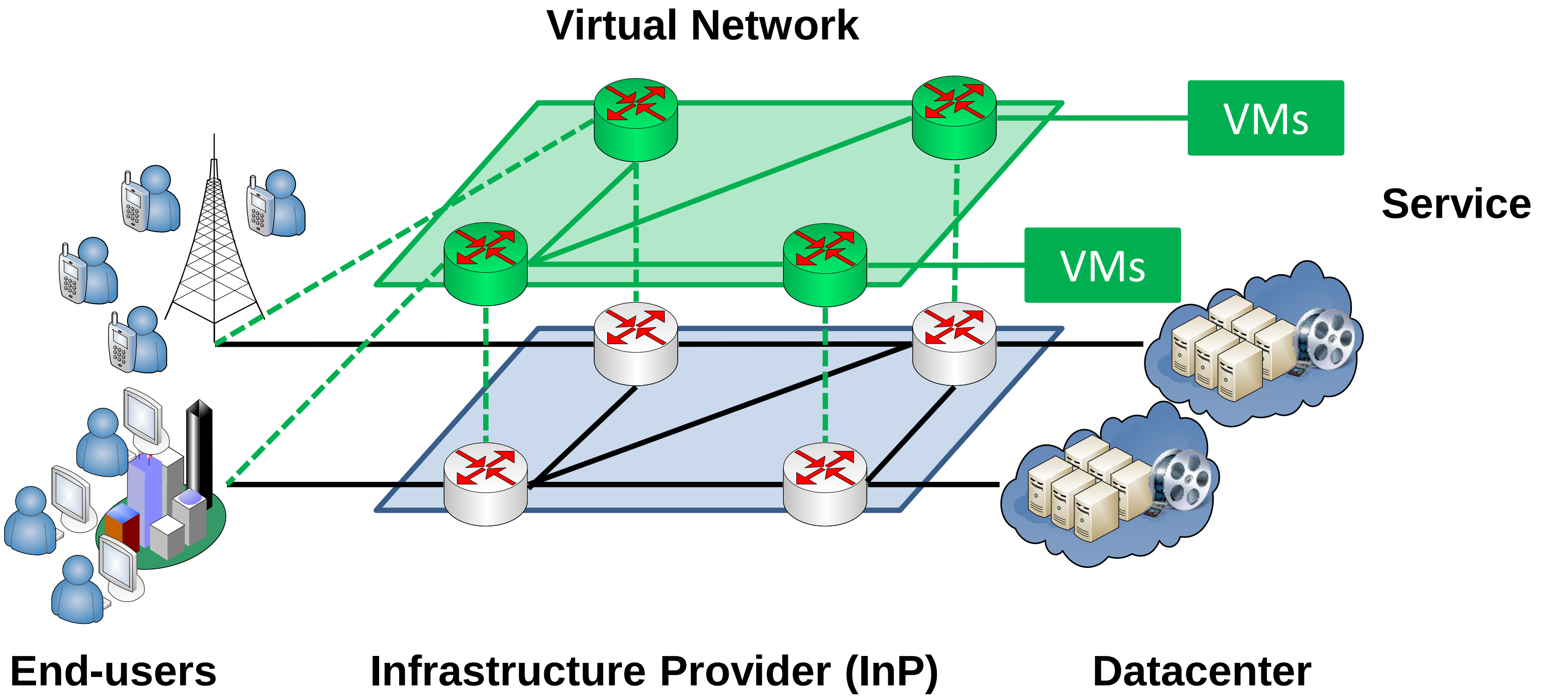


End-users **Internet Service Provider (ISP)** **Datacenter**

- Users demand for different types of services and content, e.g., (Video, Office Applications, etc.)
- Data of different services still transmitted on best effort basis
- Current architecture called to be ossified
- Virtualization helped address myriad problems [1]

[1] Douglis, Krieger, „Virtualization“, in IEEE Internet Computing, 2013

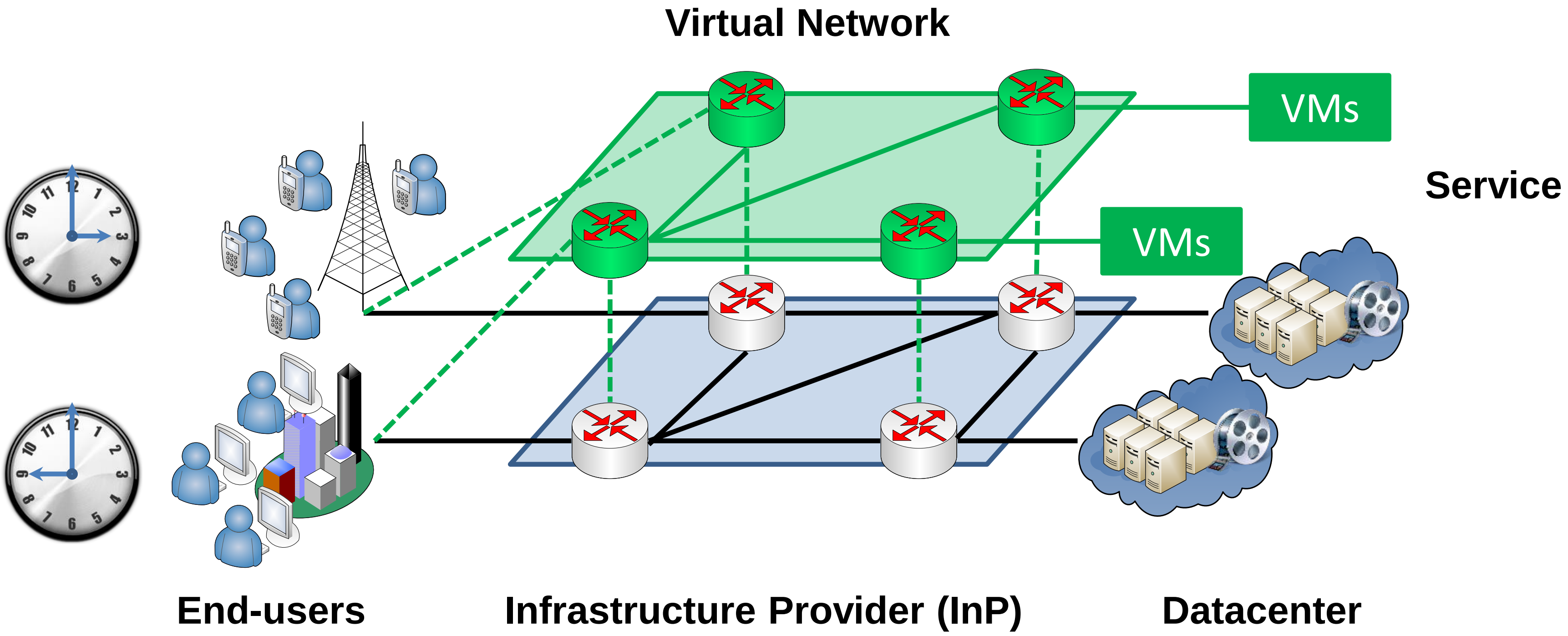
Motivation



- SP demands service specific topology
- SP manages virtual resources according to service demands
- Virtualization allows to innovate, e.g., wide area multicast IPTV [1]

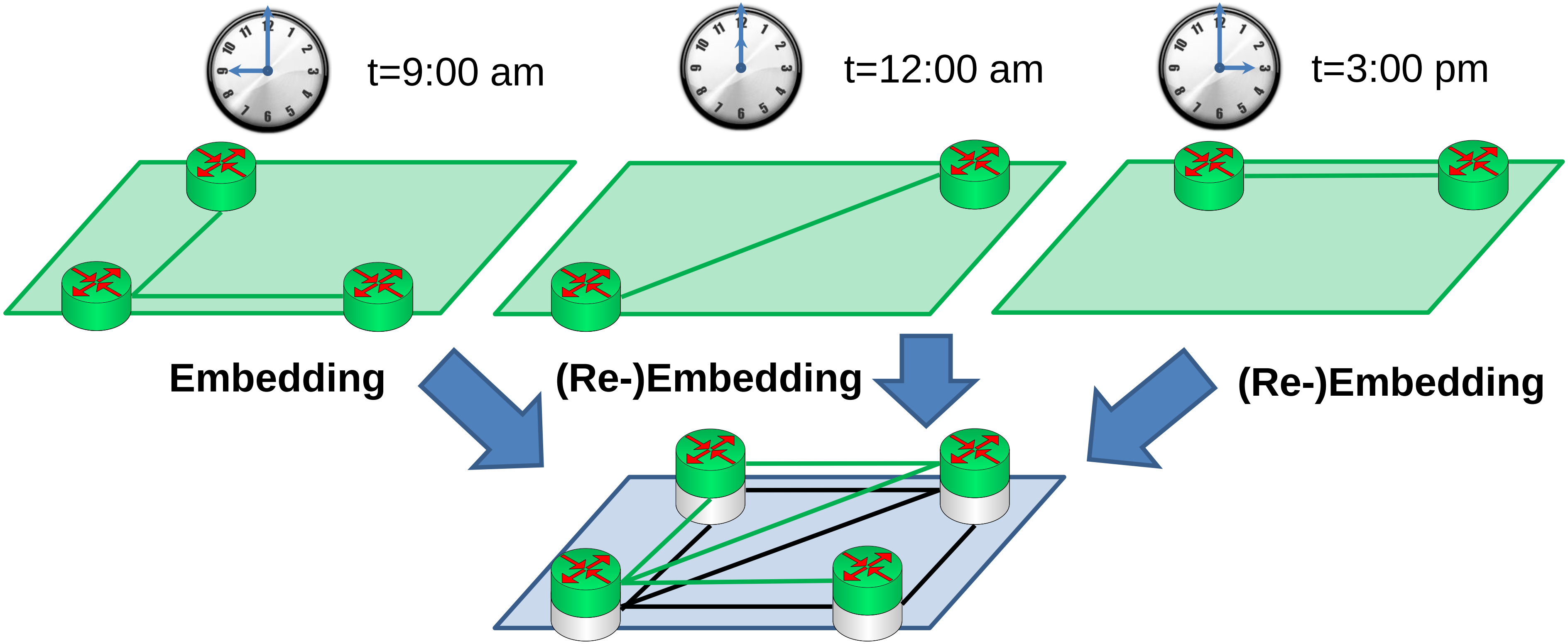
[1] Zhu, Shen, Rangarajan, Rexford „Cabernet: Connectivity Architecture for Better Network Services“, in ACM CoNEXT, 2008

Problem



- Virtual Network Embedding algorithms optimize resource allocation (Utilization, QoS)
- Most embedding algorithms assume static virtual network demands
- But VN demands should change over time → Re-Embedding

Re-embedding Problem Formulation



t=9:00 am

t=12:00 am

t=3:00 pm

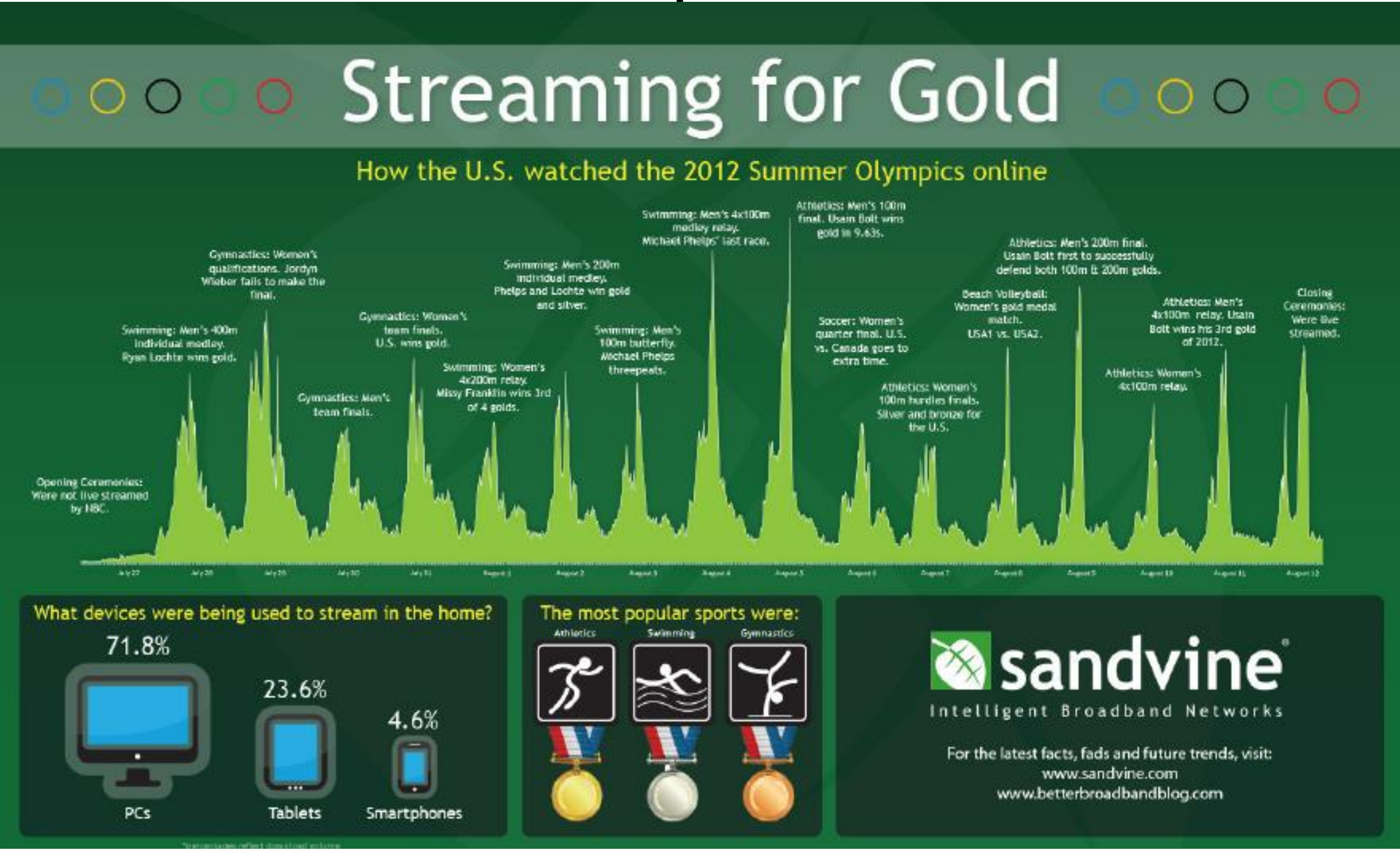
Embedding

(Re-)Embedding

(Re-)Embedding

- InP has to re-embed VNs (Re-Embedding)
- Leads to Reconfigurations (Link migrations, Node migrations)
- Find an embedding that avoids reconfigurations
- Our solution: Assume knowledge about traffic patterns (future demands)

Sandvine – Global Internet Phenomena Report



Streaming for Gold

How the U.S. watched the 2012 Summer Olympics online

Opening Ceremonies: Were not live streamed by NBC.

Swimming: Men's 400m individual medley. Ryan Lochte wins gold.

Gymnastics: Women's qualifications. Jordyn Wieber fails to make the final.

Gymnastics: Men's team finals.

Gymnastics: Women's team finals. U.S. wins gold.

Swimming: Women's 4x200m relay. Missy Franklin wins 3rd of 4 golds.

Swimming: Men's 200m individual medley. Phelps and Lochte win gold and silver.

Swimming: Men's 100m butterfly. Michael Phelps threepeats.

Swimming: Men's 4x100m medley relay. Michael Phelps' last race.

Athletics: Men's 100m final. Usain Bolt wins gold in 9.63s.

Soccer: Women's quarter final. U.S. vs. Canada goes to extra time.

Athletics: Women's 100m hurdles finals. Silver and bronze for the U.S.

Beach Volleyball: Women's gold medal match. USA1 vs. USA2.

Athletics: Men's 200m final. Usain Bolt first to successfully defend both 100m & 200m golds.

Athletics: Women's 4x100m relay.

Athletics: Men's 4x100m relay. Usain Bolt wins his 3rd gold of 2012.

Closing Ceremonies: Were live streamed.

What devices were being used to stream in the home?

PCs	Tablets	Smartphones
71.8%	23.6%	4.6%

The most popular sports were:

*percentages reflect download volume

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[1] Sandvine, "Global Internet Phenomena Report", 2012

Traffic Pattern-based Virtual Network Embedding

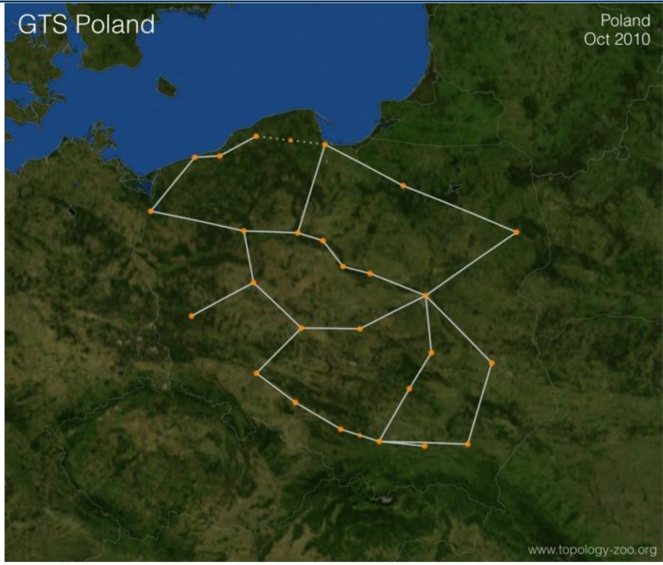
- Traffic Patterns
  - Based on spatial and temporal user behavior
  - Periodically repeating
  - Partly predictable

- Impact of reconfigurations depends also on technology
  - Link migrations in MPLS Networks [1]
  - Controller migrations in OpenFlow based Networks

- Investigation of different embedding algorithms
  - Pure load balancing (PLB)
  - Load balancing + Considering reconfiguration (LR)
  - Load balancing + Considering reconfiguration + Knowledge about demand progress (TP)

[1] Pathak et al. “Latency inflation with MPLS-based traffic engineering”, in Proceedings of the 2011 ACM SIGCOMM conference on Internet measurement conference - IMC ’11

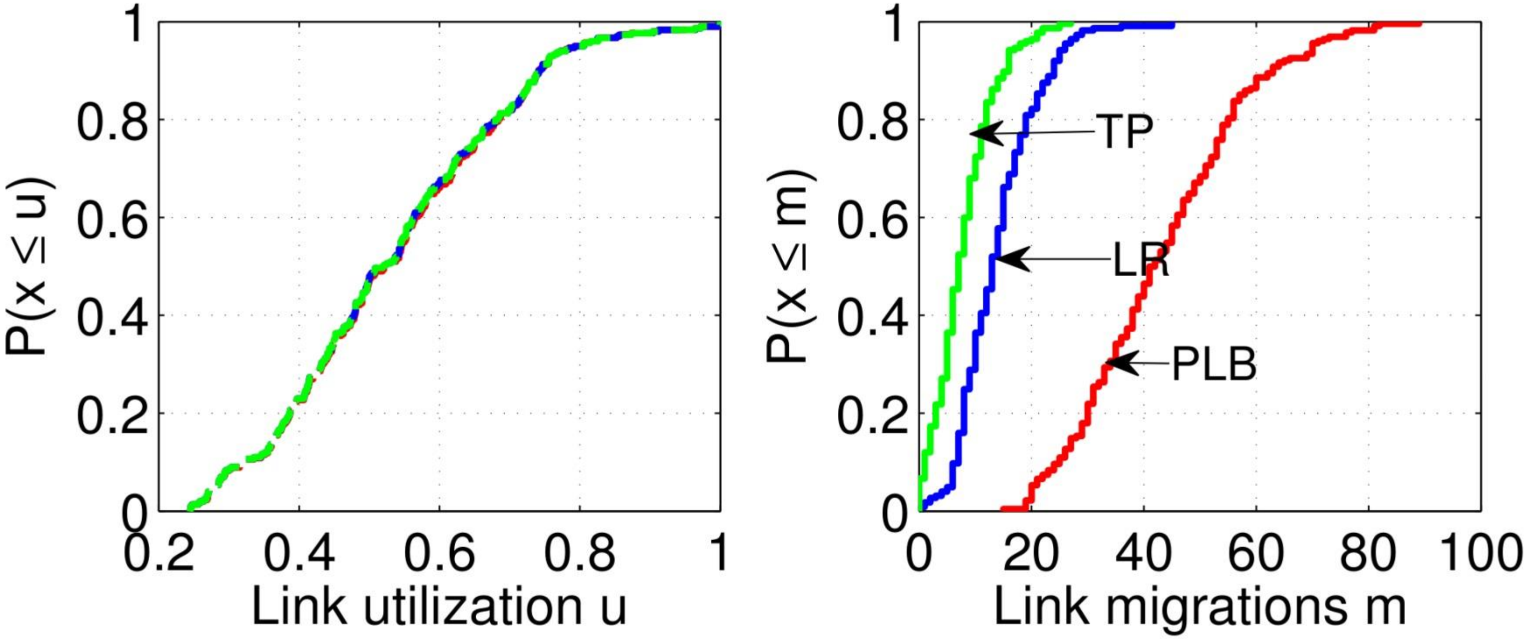
Simulation Setup for a Proof of Concept



- Physical Network
  - 12 Nodes
  - 14 Links
  - Unlimited Link Capacity
  - Unlimited Node Capacity
- 6 Virtual Networks
  - 6 to 12 Virtual Nodes
  - No Node Demands
  - Link Demands varie randomly from 4 to 200
- 75 Runs
- Unsplittable Flows

Optimization Objective: Balanced Link Load + Avoiding Link Migrations

First Simulation Results (1/2)

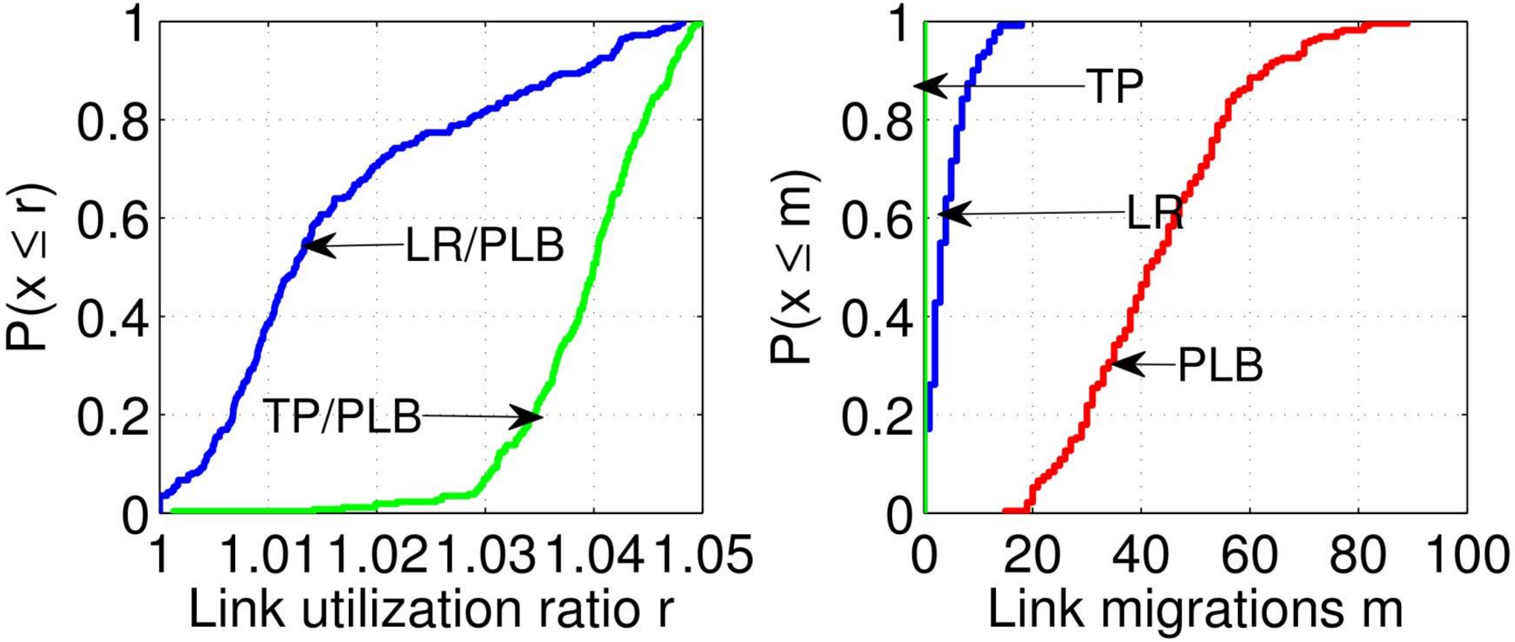


- Equal solution in terms of utilization
- TP and LR decrease link migrations

[1] Andreas Blenk and Wolfgang Kellerer. “Traffic pattern based Virtual Network Embedding”, to be published in Proceedings of the 2013 ACM CoNEXT Student Workshop

First Simulation Results (2/2)

- Setup: Accepting 5% higher link utilization



- Improves amount of reconfigurations

Summary and Outlook

- Virtualization offers more flexibility but may introduce additional reconfiguration overhead

- First re-embedding approach based on traffic patterns

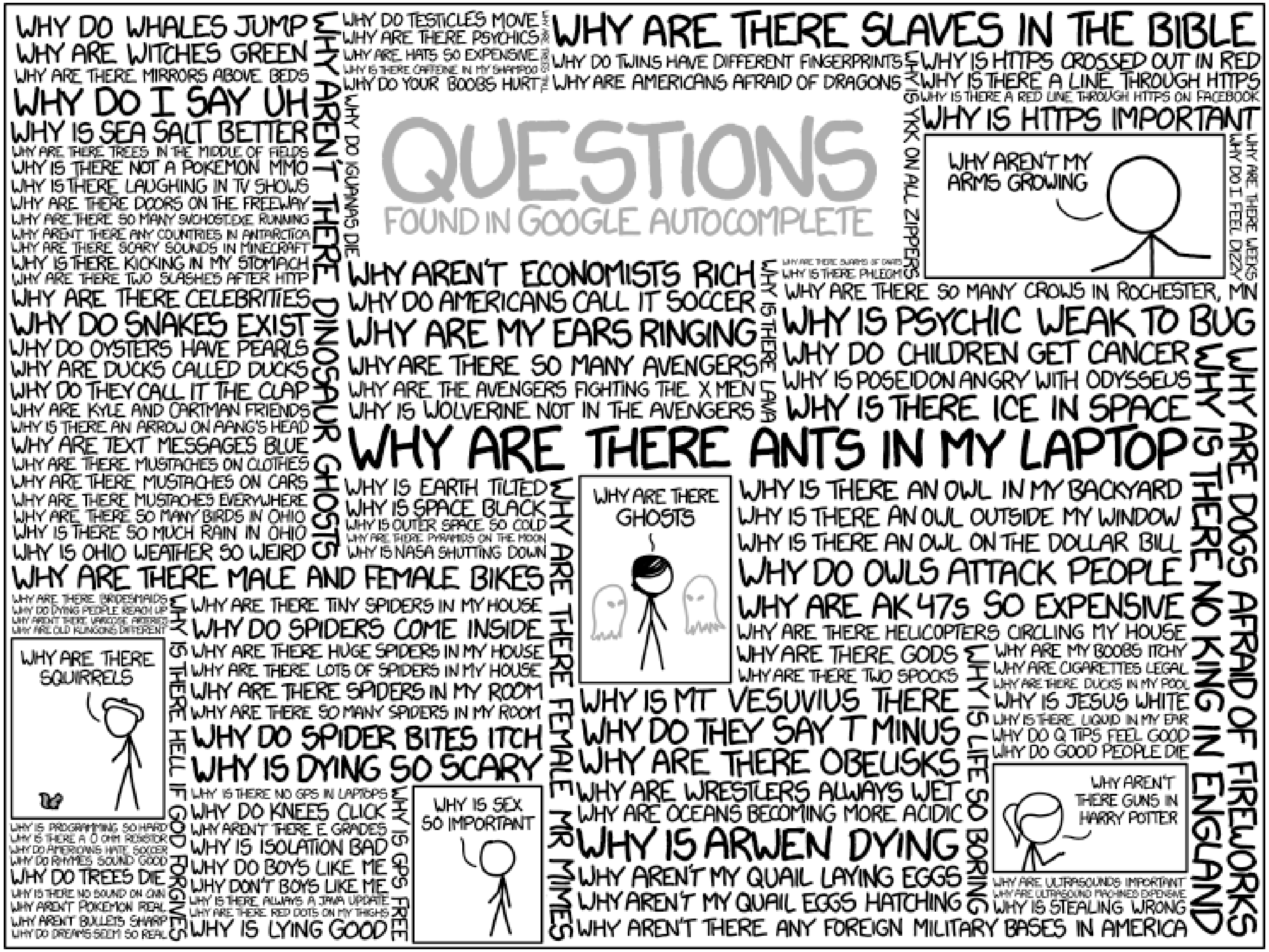
→ Assume to have knowledge about future demands

- First simulation results
  - Minimize reconfigurations, i.e., virtual link migrations
  - Algorithm does not diminish network utilization

  → Potential for further improvements

- Outlook
  - Integrate missing constraints (Capacity, Real Patterns)
  - Integrate uncertainty into the patterns
  - Analyze reconfigurations according to use case/architecture (SDN)
  - Focus on control plane architectures considering reconfigurations

Questions?


QUESTIONS
FOUND IN GOOGLE AUTOCOMPLETE
WHY DO WHALES JUMP
WHY ARE WITCHES GREEN
WHY ARE THERE MIRRORS ABOVE BEDS
WHY DO I SAY UH
WHY IS SEA SALT BETTER
WHY ARE THERE TREES IN THE MIDDLE OF FIELDS
WHY IS THERE NOT A POKEMON MMO
WHY IS THERE LAUGHING IN TV SHOWS
WHY ARE THERE DOORS ON THE FREEWAY
WHY ARE THERE SO MANY SVCHOST.EXE RUNNING
WHY AREN'T THERE ANY COUNTRIES IN ANTARCTICA
WHY ARE THERE SCARY SOUNDS IN MINECRAFT
WHY IS THERE KICKING IN MY STOMACH
WHY ARE THERE TWO SLASHES AFTER HTTP
WHY ARE THERE CELEBRITIES
WHY DO SNAKES EXIST
WHY DO OYSTERS HAVE PEARLS
WHY ARE DUCKS CALLED DUCKS
WHY DO THEY CALL IT THE CLAP
WHY ARE KYLE AND CARTMAN FRIENDS
WHY IS THERE AN ARROW ON AANG'S HEAD
WHY ARE TEXT MESSAGES BLUE
WHY ARE THERE MUSTACHES ON CLOTHES
WHY ARE THERE MUSTACHES ON CARS
WHY ARE THERE MUSTACHES EVERYWHERE
WHY ARE THERE SO MANY BIRDS IN OHIO
WHY IS THERE SO MUCH RAIN IN OHIO
WHY IS OHIO WEATHER SO WEIRD
WHY AREN'T THERE DINOSAUR GHOSTS
WHY DO IGUANAS DIE
WHY DO TESTICLES MOVE
WHY ARE THERE PSYCHICS
WHY ARE HATS SO EXPENSIVE
WHY IS THERE CAFFEINE IN MY SHAMPOO
WHY DO YOUR BOOBS HURT
WHY ARE THERE SLAVES IN THE BIBLE
WHY DO TWINS HAVE DIFFERENT FINGERPRINTS
WHY ARE AMERICANS AFRAID OF DRAGONS
WHY IS YKK ON ALL ZIPPERS
WHY IS HTTPS CROSSED OUT IN RED
WHY IS THERE A LINE THROUGH HTTPS
WHY IS THERE A RED LINE THROUGH HTTPS ON FACEBOOK
WHY IS HTTPS IMPORTANT
WHY AREN'T MY ARMS GROWING
WHY ARE THERE WEEKS
WHY DO I FEEL DIZZY
WHY AREN'T ECONOMISTS RICH
WHY DO AMERICANS CALL IT SOCCER
WHY ARE MY EARS RINGING
WHY ARE THERE SO MANY AVENGERS
WHY ARE THE AVENGERS FIGHTING THE X MEN
WHY IS WOLVERINE NOT IN THE AVENGERS
WHY IS THERE LAVA
WHY ARE THERE SWARMS OF GNATS
WHY IS THERE PHLEGM
WHY ARE THERE SO MANY CROWS IN ROCHESTER, MN
WHY IS PSYCHIC WEAK TO BUG
WHY DO CHILDREN GET CANCER
WHY IS POSEIDON ANGRY WITH ODYSSEUS
WHY IS THERE ICE IN SPACE
WHY ARE THERE ANTS IN MY LAPTOP
WHY IS THERE NO KING IN ENGLAND
WHY ARE DOGS AFRAID OF FIREWORKS
WHY IS EARTH TILTED
WHY IS SPACE BLACK
WHY IS OUTER SPACE SO COLD
WHY ARE THERE PYRAMIDS ON THE MOON
WHY IS NASA SHUTTING DOWN
WHY ARE THERE MALE AND FEMALE BIKES
WHY ARE THERE GHOSTS
WHY ARE THERE FEMALE MR MIMES
WHY IS THERE AN OWL IN MY BACKYARD
WHY IS THERE AN OWL OUTSIDE MY WINDOW
WHY IS THERE AN OWL ON THE DOLLAR BILL
WHY DO OWLS ATTACK PEOPLE
WHY ARE AK 47s SO EXPENSIVE
WHY ARE THERE HELICOPTERS CIRCLING MY HOUSE
WHY ARE THERE GODS
WHY ARE THERE TWO SPOCKS
WHY ARE MY BOOBS ITCHY
WHY ARE CIGARETTES LEGAL
WHY ARE THERE DUCKS IN MY POOL
WHY IS JESUS WHITE
WHY IS THERE LIQUID IN MY EAR
WHY DO Q TIPS FEEL GOOD
WHY DO GOOD PEOPLE DIE
WHY AREN'T THERE GUNS IN HARRY POTTER
WHY ARE ULTRASOUNDS IMPORTANT
WHY ARE ULTRASOUND MACHINES EXPENSIVE
WHY IS STEALING WRONG
WHY IS LIFE SO BORING
WHY IS MT VESUVIUS THERE
WHY DO THEY SAY T MINUS
WHY ARE THERE OBELISKS
WHY ARE WRESTLERS ALWAYS WET
WHY ARE OCEANS BECOMING MORE ACIDIC
WHY IS ARWEN DYING
WHY AREN'T MY QUAIL LAYING EGGS
WHY AREN'T MY QUAIL EGGS HATCHING
WHY AREN'T THERE ANY FOREIGN MILITARY BASES IN AMERICA
WHY ARE THERE BRIDESMAIDS
WHY DO DYING PEOPLE REACH UP
WHY AREN'T THERE VARICOSE ARTERIES
WHY ARE OLD KLINGONS DIFFERENT
WHY IS THERE HELL IF GOD FORGIVES
WHY ARE THERE SQUIRRELS
WHY IS PROGRAMMING SO HARD
WHY IS THERE A 0 OHM RESISTOR
WHY DO AMERICANS HATE SOCCER
WHY DO RHYMES SOUND GOOD
WHY DO TREES DIE
WHY IS THERE NO SOUND ON CNN
WHY AREN'T POKEMON REAL
WHY AREN'T BULLETS SHARP
WHY DO DREAMS SEEM SO REAL
WHY ARE THERE TINY SPIDERS IN MY HOUSE
WHY DO SPIDERS COME INSIDE
WHY ARE THERE HUGE SPIDERS IN MY HOUSE
WHY ARE THERE LOTS OF SPIDERS IN MY HOUSE
WHY ARE THERE SPIDERS IN MY ROOM
WHY ARE THERE SO MANY SPIDERS IN MY ROOM
WHY DO SPIDER BITES ITCH
WHY IS DYING SO SCARY
WHY IS THERE NO GPS IN LAPTOPS
WHY DO KNEES CLICK
WHY AREN'T THERE E GRADES
WHY IS ISOLATION BAD
WHY DO BOYS LIKE ME
WHY DON'T BOYS LIKE ME
WHY IS THERE ALWAYS A JAVA UPDATE
WHY ARE THERE RED DOTS ON MY THIGHS
WHY IS LYING GOOD
WHY IS GPS FREE
WHY IS SEX SO IMPORTANT

Thank you!