A NETWORK SCIENCE BASED APPROACH FOR OPTIMAL MICROSERVICE GOVERNANCE

2020-021

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Supervisor
Dr. Dharshana Kasthurirathna

Introduction

- Why Micro-Services ?
- Current trends and practices in Micro-Services
- Why Kubernetes ?
- Problem definition

Problems

Constant monitoring of metrics through APM tools. E.g.-Resource utilization process[1-2]

Difficult to understand why a problem occurs even though there is knowledge that a problem has occurred[5]

Have to make use of multiple monitoring sources to make effective decisions[3-5]

In short the research problem that our research aims to fulfil can simply be described as follows

"In deploying Microservices through Kubernetes, there is no efficient and effective way for developers to evaluate and monitor the effectiveness and viability of a microservice deployment and identify possible performance bottlenecks. Furthermore, developers are not able to optimize their deployment such that they can make the optimal use of their deployed microservices in the cluster."

Research Questions

Can current orchestration tools successfully monitor relationships among microservices ?

How effective is the proposed optimization model compared to current optimization models ?

What is the impact of pod load prediction in determining an optimal deployment strategy ?

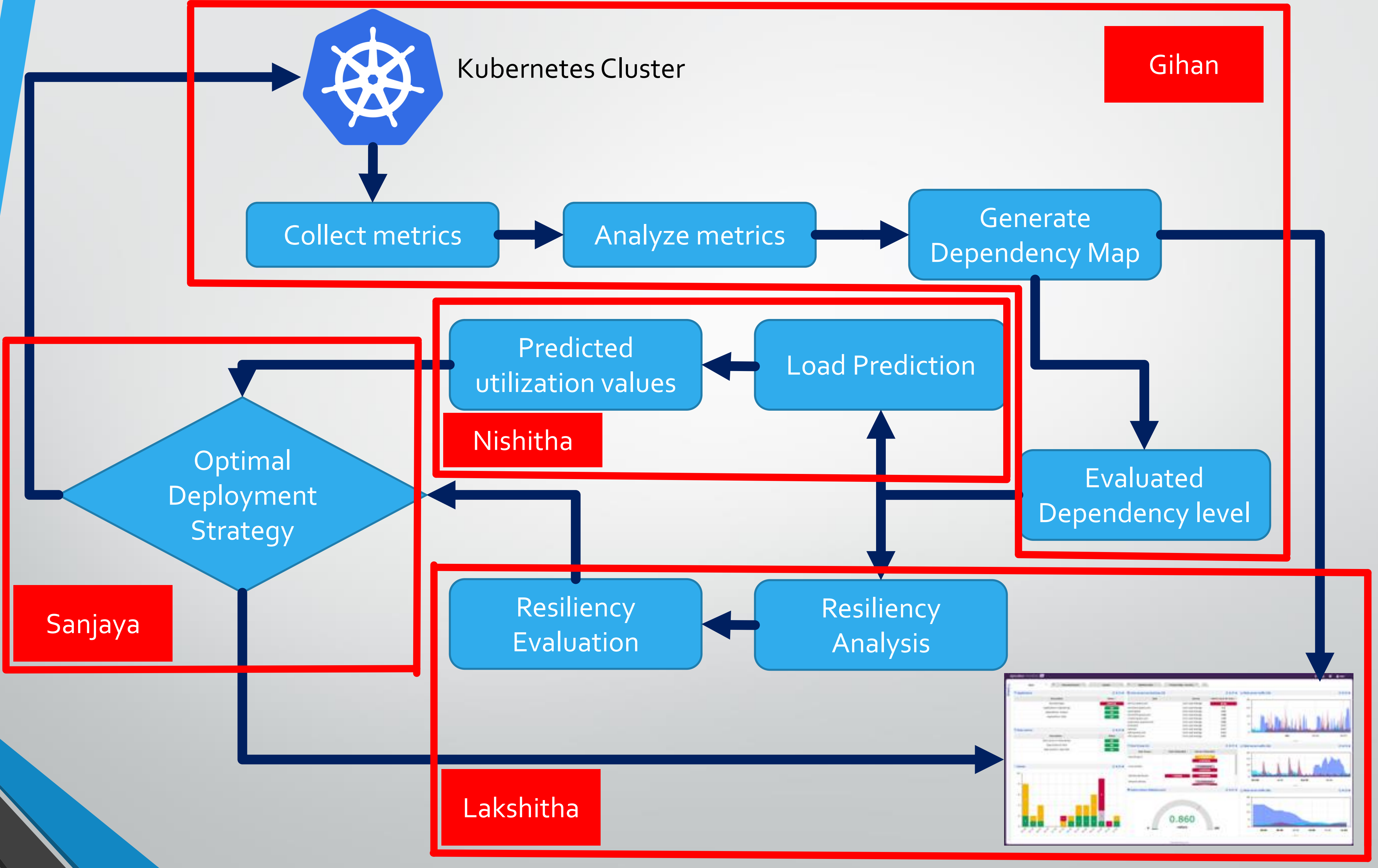
What is the importance and the impact of identifying the resiliency of microservices in deployments ?

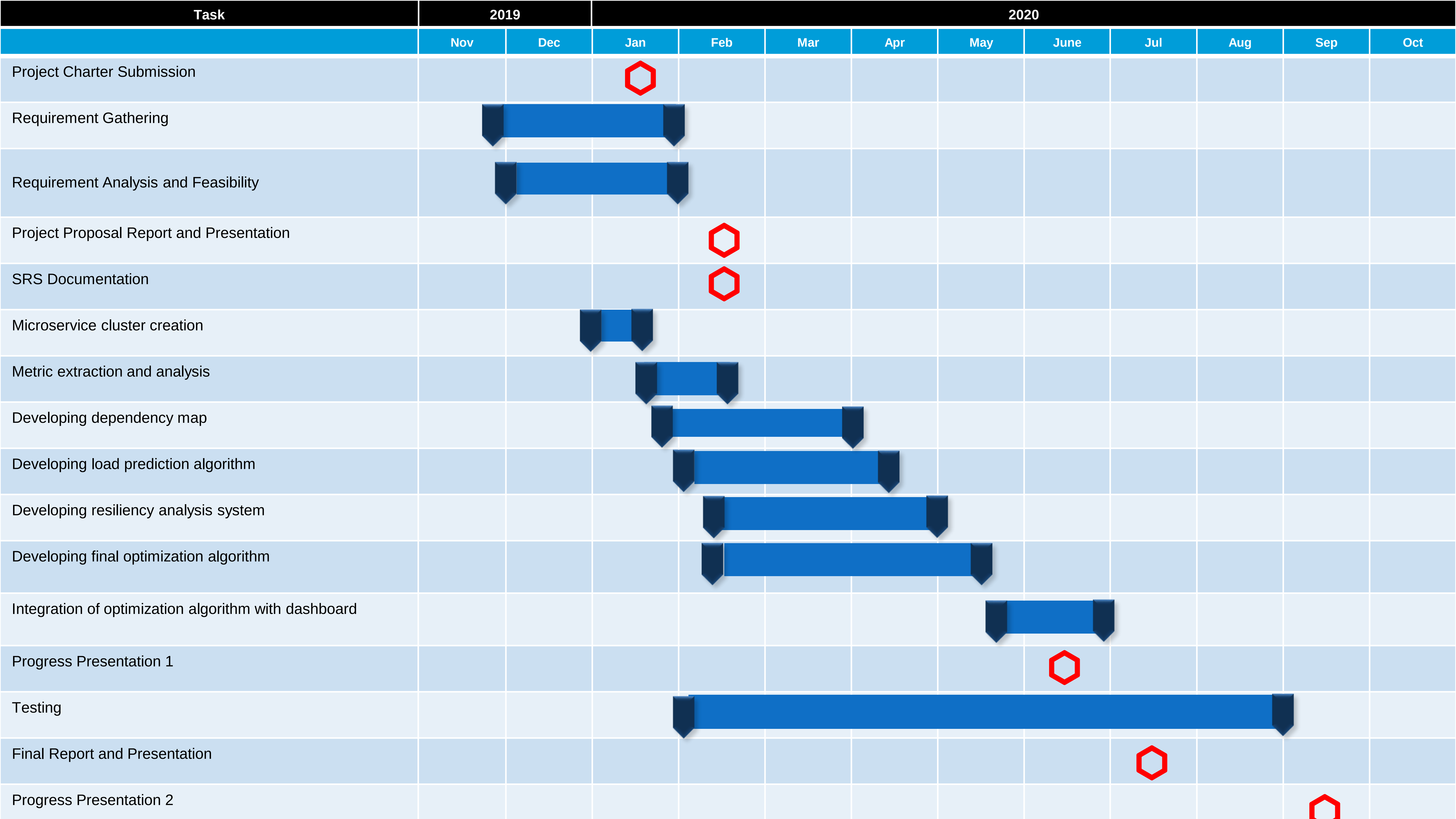
Main Objective

To model a network science-based approach to govern microservice deployments through evaluation and analysis of metrics gathered, and ultimately produce a proposed model which aids to optimize microservice deployments.

Sub Objectives

- To increase the efficiency of microservices deployments by applying the metrics used in network analysis, such as centrality and resilience measures and link predictions on identified dependency measurements.
- To develop an improved auto-scaling policy for a deployment, based on load prediction
- To development of a business intelligence dashboard to evaluate performance and monitor microservice deployments.
- To identify key factors which lead to performance reduction in microservice deployments and come up with an optimal deployment strategy.


Kubernetes Cluster
Gihan
Collect metrics
Analyze metrics
Generate Dependency Map
Predicted utilization values
Load Prediction
Nishitha
Optimal Deployment Strategy
Evaluated Dependency level
Sanjaya
Resiliency Evaluation
Resiliency Analysis
Lakshitha


Task
2019
2020
Nov
Dec
Jan
Feb
Mar
Apr
May
June
Jul
Aug
Sep
Oct
Project Charter Submission
Requirement Gathering
Requirement Analysis and Feasibility
Project Proposal Report and Presentation
SRS Documentation
Microservice cluster creation
Metric extraction and analysis
Developing dependency map
Developing load prediction algorithm
Developing resiliency analysis system
Developing final optimization algorithm
Integration of optimization algorithm with dashboard
Progress Presentation 1
Testing
Final Report and Presentation
Progress Presentation 2

Requirements

Functional Requirements

- User should be able to view optimal deployment strategy for a given cluster
- User should be able to view possible deployment suggestions in order to optimize the deployment
- System should analyze the resiliency of the identified microservices in the cluster
- Load prediction should be performed on the identified microservices
- Load predictions should be made based for a maximum of 24hrs ahead
- Auto scaler should be configured to proactively auto scale based on predicted load
- Optimal deployment strategy for a particular deployment should be determined using load prediction, dependency measurements and resiliency evaluation

Requirements

Non Functional Requirements

- Usability
- Reliability
- Availability
- Interoperability
- Performance

Expected Outcomes

- To create a weight-based dependency network using metric analysis which highlights dependencies between the interconnected microservices.
- To create an improved auto-scaling policy integrating load-prediction analysis.
- To improve the performance of microservice deployments through resiliency analysis.
- To increase the performance in microservice deployments through the combination of the above-mentioned approaches.

Commercialization

Initial plan is develop model into an open source tool.

In the future, with the addition of newer features, we plan on making this tool a freemium tool.

A network science based approach for the generation of dependency map and a service mesh based on the network traffic and user behavior on a Kubernetes cluster

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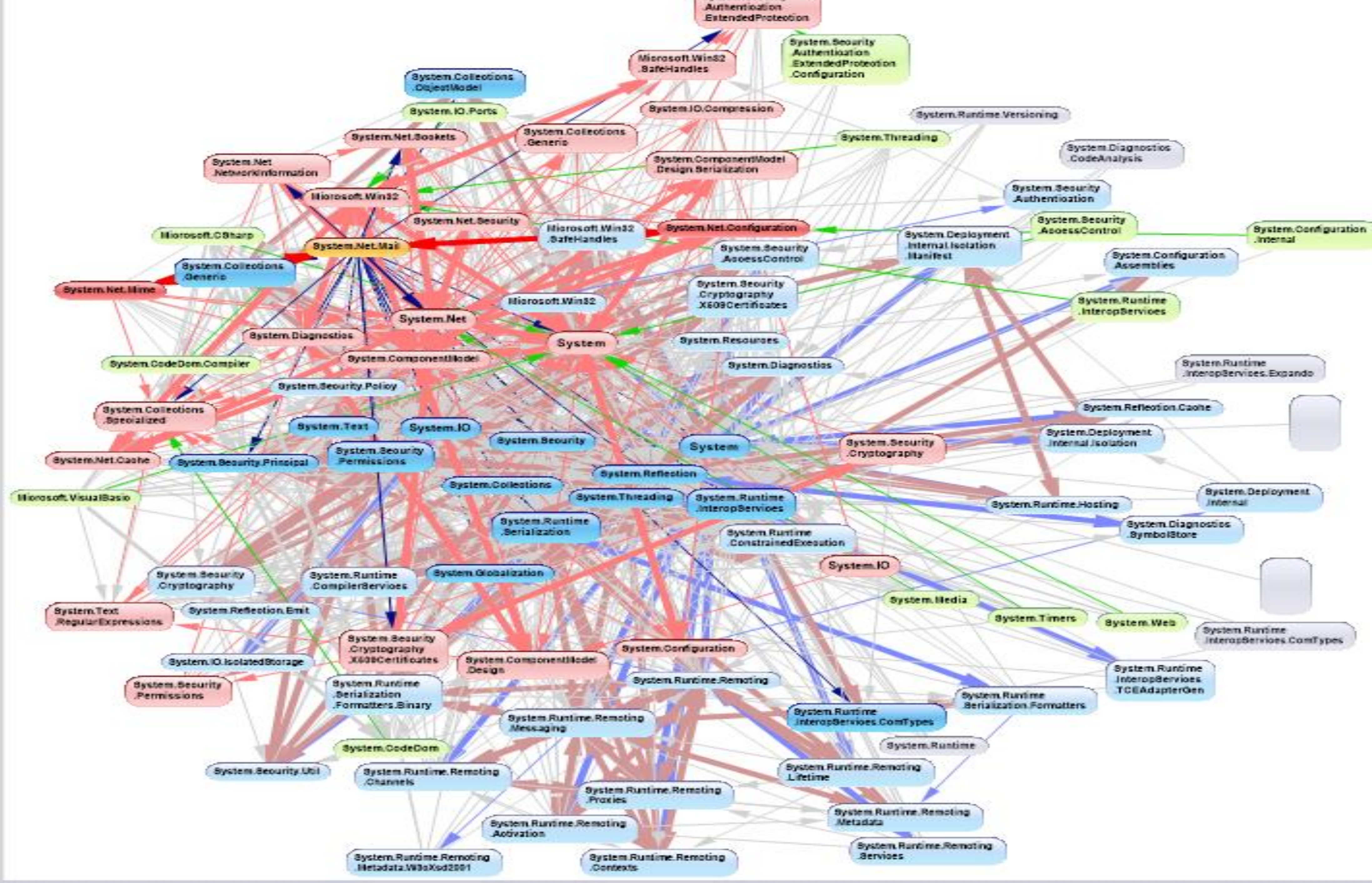
Introduction

- How Kubernetes works ?
- What is a service mesh ?
- Service Gateway
- Problem definition

Grafana
enterprise

JAEGER

kiali



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System.Collections .ObjectModel
System.IO.Ports
System.IO.Compression
System.Runtime.Versioning
System.Net.Sockets
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System.Threading
System.Diagnostics .CodeAnalysis
System.Net .NetworkInformation
System.ComponentModel .Design.Serialization
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System.Configuration .Internal
Microsoft.CSharp
System.Net.Mail
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System.Deployment .Internal.Isolation .Manifest
System.Collections .Generic
System.Configuration .Assemblies
System.Net.Mime
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System.Resources
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System.Media
System.Timers
System.Web
System.Runtime .InteropServices.ComTypes
System.Text .RegularExpressions
System.Reflection.Emit
System.Security .Cryptography .X509Certificates
System.Configuration
System.IO.IsolatedStorage
System.ComponentModel .Design
System.Runtime.Remoting
System.Runtime .InteropServices .TCEAdapterGen
System.Security .Permissions
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System.Runtime.Remoting .Services
System.Runtime.Remoting .Metadata.W3cXsd2001
System.Runtime.Remoting .Contexts

Related Research and Research Gap

- [1]Istio: Modernize digital applications with microservices management using the istio service mesh
- [4 Service Dependency Based Dynamic Load Balancing Algorithm for Container Clusters
- Deploying Microservice Based Applications with Kubernetes: Experiments and Lessons Learned

A data science based approach for an improved auto-scaling policy in Kubernetes based on load prediction

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Introduction

- What is autoscaling ?
- Current Autoscaling tools by Kubernetes
- What is Kubernetes HPA and how it works ?
- Problems in the current implementation of HPA
- Why we focused about issues in HPA ?

Problems faced in the current implementation of HPA

I. Response delay caused by the time required for Pod initialization[1,7]

II. Response delay causes increases the user's request response time, resulting drop in service quality [1,7]

III. Ineffective scaling caused due to the under allocation of resources in the configuration process[1,7]

Related Research

- [1] Uses a combination of ARIMA model and Empirical Mode Decomposition (EMD) in order to predict resource usage
  - Highlights current issues such as the response delay in Kubernetes
  - However, the use of EMD model has some drawbacks explained in [2]
- [3] Proposes a resource prediction algorithm called CRUPA
  - The CRUPA algorithm is based on a time series analysis model (ARIMA) combined with docker container techniques.
  - However this approach does integrate with existing auto-scaling tools provided by Kubernetes as well as does not make use of machine learning tools in order to perform the prediction process.
- [4-6] compares various models for short term load forecasting and their prediction accuracy

Objective

- To develop an improved auto-scaling policy for a deployment, based on load prediction

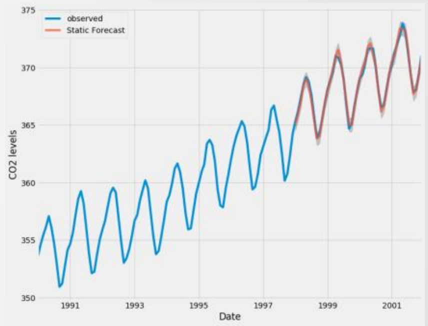
Research Questions

- What is the impact of load prediction in coming up with an optimal deployment strategy ?
- How accurately can we predict utilization values ?
- What is the impact of load prediction on the identified microservices in the overall performance of the cluster ?

Steps in the development of load prediction algorithm

1. Obtain the list microservices that show high level of dependency based on the proposed dependency map
2. Identify the relevant pods in which the identified microservices are deployed
3. Obtain the CPU utilization metrics of the deployed pods
4. Convert the metrics obtained into a time series

Steps in the development of load prediction algorithm cont.



1. Plot time series to identify the relevant time series components
2. Convert time series to a stationary dataset
3. Develop algorithm using prediction model to forecast future CPU utilization values for given pods
4. Forecasted CPU utilization values will be forwarded to optimization algorithm and used to configure auto-scaling of the cluster

Expected Outcome

To create an improved auto-scaling policy integrating load-prediction analysis which solves the current issues found in the HPA in Kubernetes

A network science based approach for evaluation of resiliency among microservices through the use of Chaos Engineering

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Introduction

- What is resilience?
- What are the ways to analyze resilience?
- What is Chaos Engineering?
- What are the tools used in Chaos Engineering?
- Importance of analyzing resilience

Currently the dependency network is not considered when measuring the importance of a service in the deployment

Related Work

- [1]Gremlin: Systematic Resilience Testing of Microservices
  - how to use Gremlin to express common failure scenarios and how developers of an enterprise application were able to discover previously unknown bugs in their failure-handling code without modifying the application.
- [4]Chaos Monkey: Increasing SDN Reliability through Systematic Network Destruction

Objectives

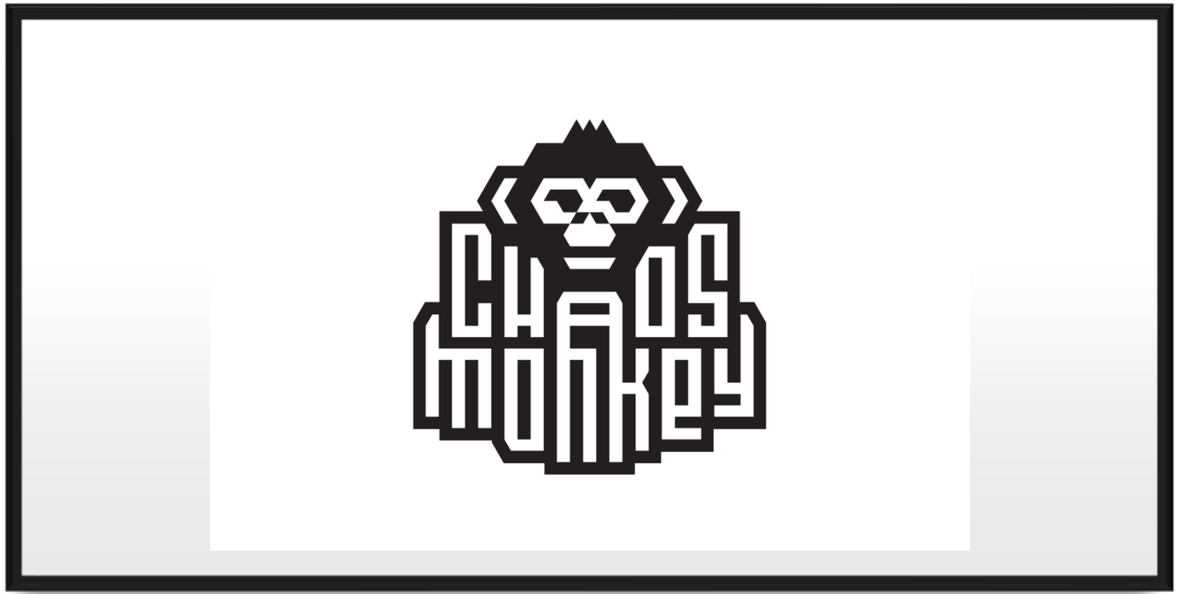
- Evaluate the resilience of microservices using Chaos Engineering to provide data to generate an optimal deployment strategy

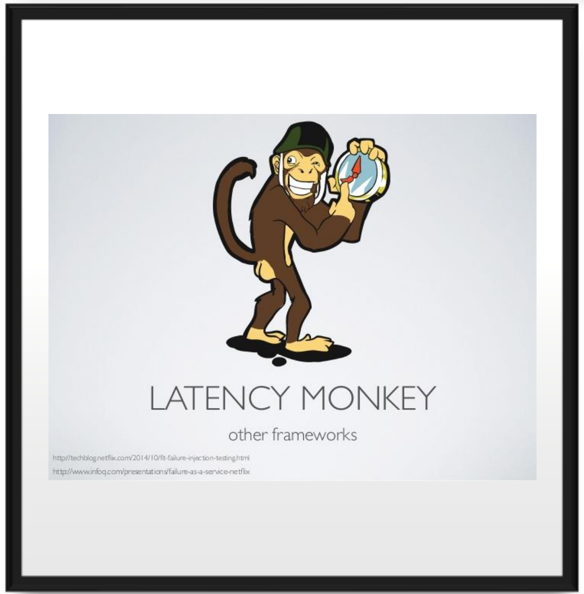
Research questions

- What are the impact of microservices on each other?
- How does the dependency network affect on the deployment of microservices?
- How to evaluate resiliency of microservices without interrupting customers?

Chaos Engineering

- Chaos Monkey - randomly kills a microservice
- Chaos Gorilla - kills entire availability zone
- Chaos Kong - kill whole reigon
- Latency Monkey - Introduces communication delays to simulate degradation or outages in a network.
- Doctor Monkey - Performs health checks, by monitoring performance metrics such as CPU load to detect unhealthy instances
- Failure Injection Testing - designed to give developers a "blast radius" rather than unmanaged chaos


CHAOS
monkey


LATENCY MONKEY
other frameworks
http://techblog.netflix.com/2014/10/fit-failure-injection-testing.html
http://www.infoq.com/presentations/failure-as-a-service-netflix

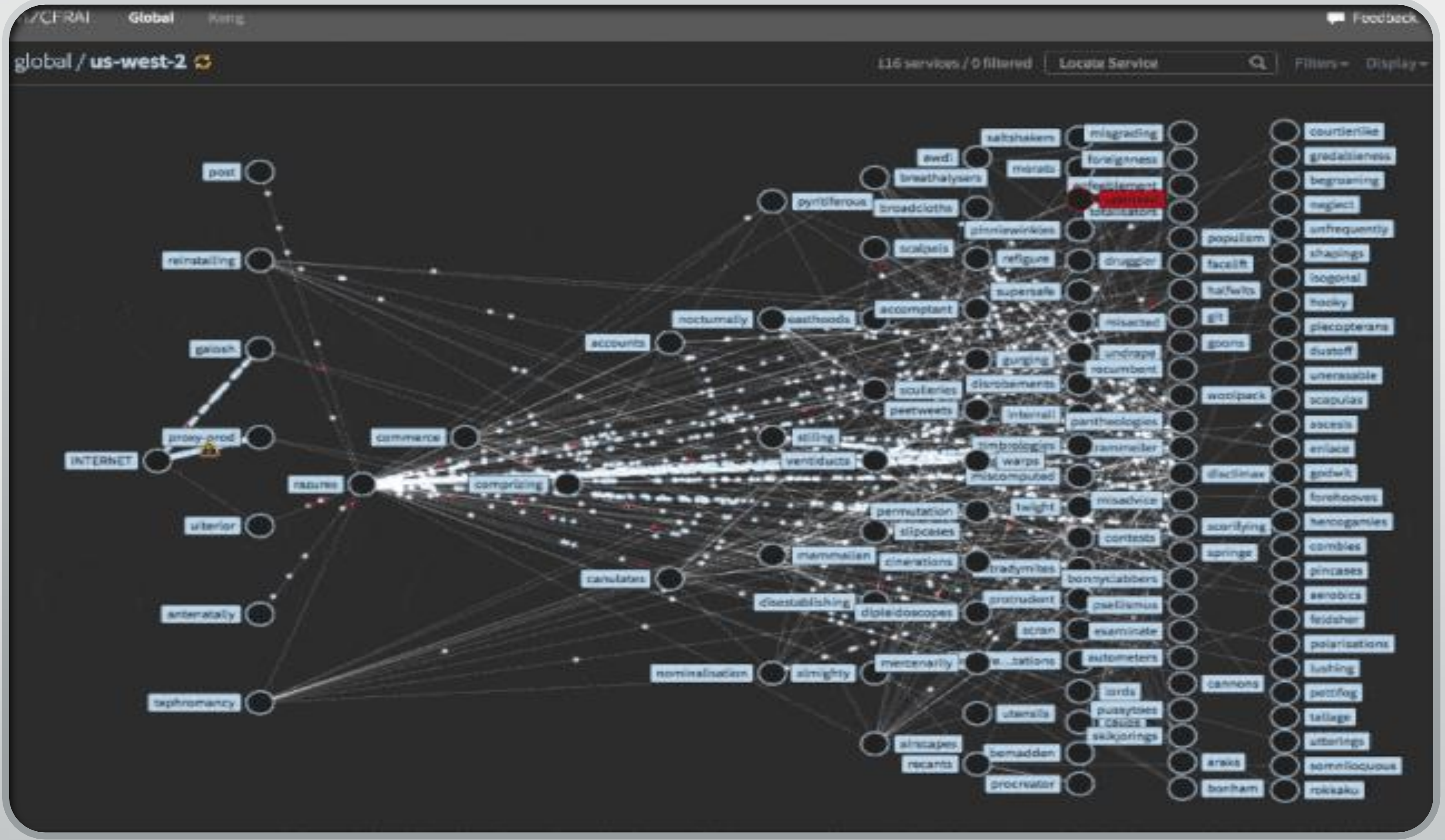

Chaos Gorilla
NETFLIX
@atseitlin


CHAOS KONG
because regions fail
http://techblog.netflix.com/2015/09/chaos-engineering-upgraded.html

Steps in designing a Chaos Experiment

1. Pick a hypothesis
2. Choose the scope of the experiment
3. Identify the metrics you're going to watch
4. Notify the organization
5. Run the experiment
6. Analyze the results
7. Increase the scope
8. Automate

Stimulating failovers to determine the highly dependent nodes



[7]How Netflix does failovers in 7 minutes flat

Expected Outcome

- To generate a detailed evaluation report on the resiliency of the microservices

A network science based approach for generating optimal deployment strategy by using dependency, load predictions and resiliency measures among microservices in Kubernetes.

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Availability and Network latency

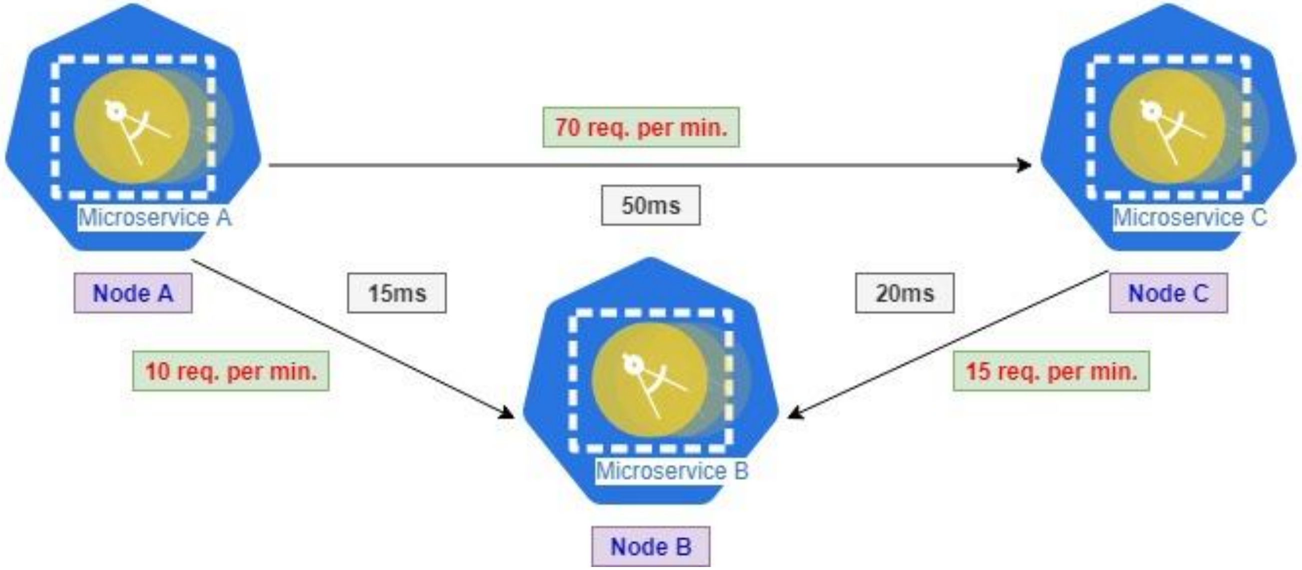
- When we deploy microservices, we deploy them in many nodes. because we need to increase availability.

- In the Kubernetes cluster, we have master node and salve nodes, these nodes can be located in the multiple places, may be another country.

- This problem causes delays between nodes. This is called network latency[2,4].

- **That is affected to overall response time[1]**

- E.g.: if network latency is high. Overall response time will be high.



Network Latency between different regions (Azure Cloud)

- Lowest latency in December: Australia central1 region – Australia central2 region(1ms)[5]
- Highest latency in December: Australia central-South Africa(392ms)[5]

	Australia Central	Australia Central2	Australia East	AustraliaSouthEast	Brazil South	Canada Central	Canada East	Central India	Central US	East Asia	East US	East US2	France Central	FranceSouth	Germany North	Germany West Central	Japan East	Japan West	Korea Central	Korea South	North Central US	North Europe	Norway East	Norway West	South Central US	South East Asia	South India	Southafrica West	SouthAfricaNorth	Switzerland North	Switzerland W
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ralia East	6	6		12	306	200	210	142	182	116	200	196	286	300	296	292	126	130	144	142	188	272	308	300	170	88	120	388	382	297	30
raliaSouthEast	18	18	12		318	210	220	140	192	118	210	206	296	310	308	302	132	136	146	140	198	282	318	310	182	86	118	386	382	308	31
il South	312	312	306	318		132	140	302	144	322	118	114	186	200	196	192	260	268	301	306	138	172	208	200	138	326	316	328	342	198	20
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US	205	206	200	210	118	25	35	196	27	200		6	80	90	90	86	168	168	181	186	18	66	102	94	32	220	209	220	234	92	8
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ceSouth	304	304	300	310	200	106	116	104	112	172	90	90	12		26	17	204	202	200	194	106	26	44	36	116	138	116	164	158	10	8
many North	302	302	296	308	196	104	114	128	118	196	90	94	20	26		10	229	228	224	218	110	26	20	26	121	162	142	164	178	16	1
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h India	126	124	120	118	316	222	232	24	228	66	209	212	129	116	142	132	100	100	94	88	228	145	158	152	222	34		279	274	126	12
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hAfricaNorth	388	388	382	382	342	248	256	262	260	328	234	238	166	158	178	174	362	360	358	352	256	172	186	180	264	296	274	18		170	16
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t India	146	144	140	138	302	208	216	4	222	86	194	196	116	102	126	118	120	120	114	108	214	130	144	138	222	52	22	265	260	114	11
t US	142	144	140	150	170	64	72	222	42	149	64	59	138	148	160	154	104	106	129	134	54	128	170	164	34	168	200	292	304	150	14
t US2	162	164	158	170	180	56	66	214	36	142	66	71	142	152	154	148	96	104	122	126	46	130	164	156	44	160	192	284	297	156	15

How to avoid from high network latency

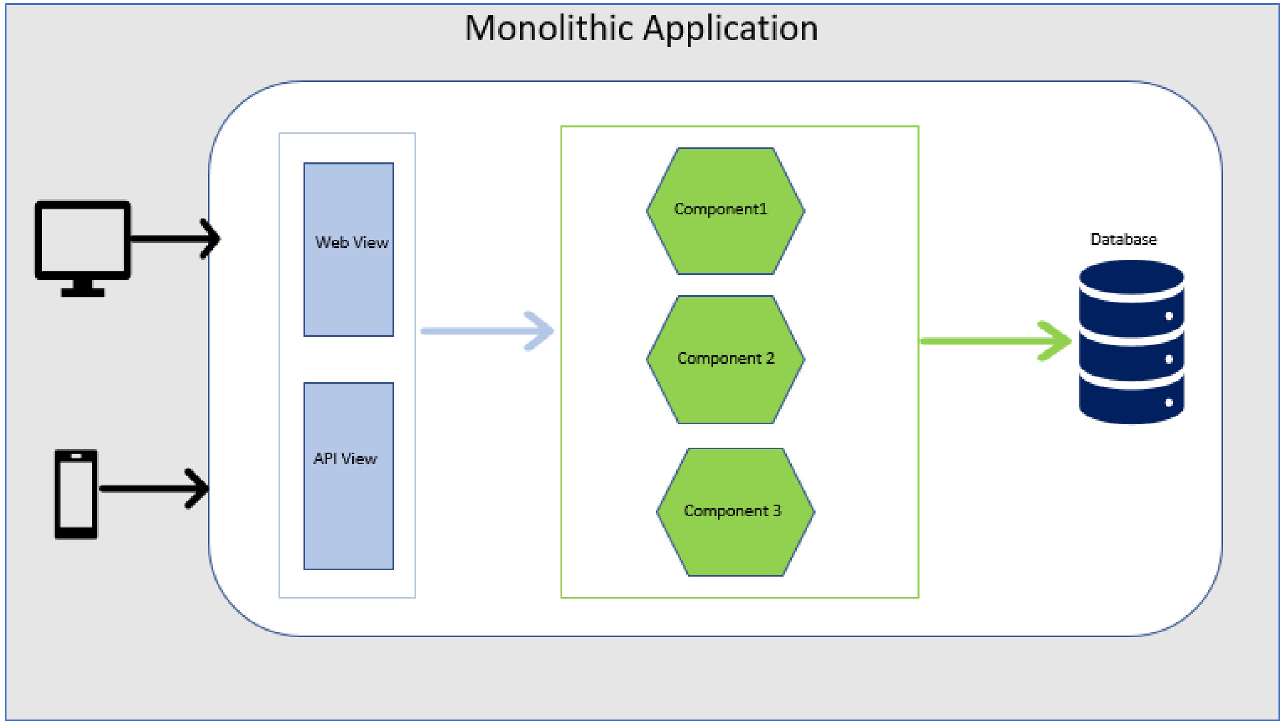
All the Microservices can be deployed in one Big Node.

Micro-services with higher communication rate can be deployed in nearby nodes.

One Big Node

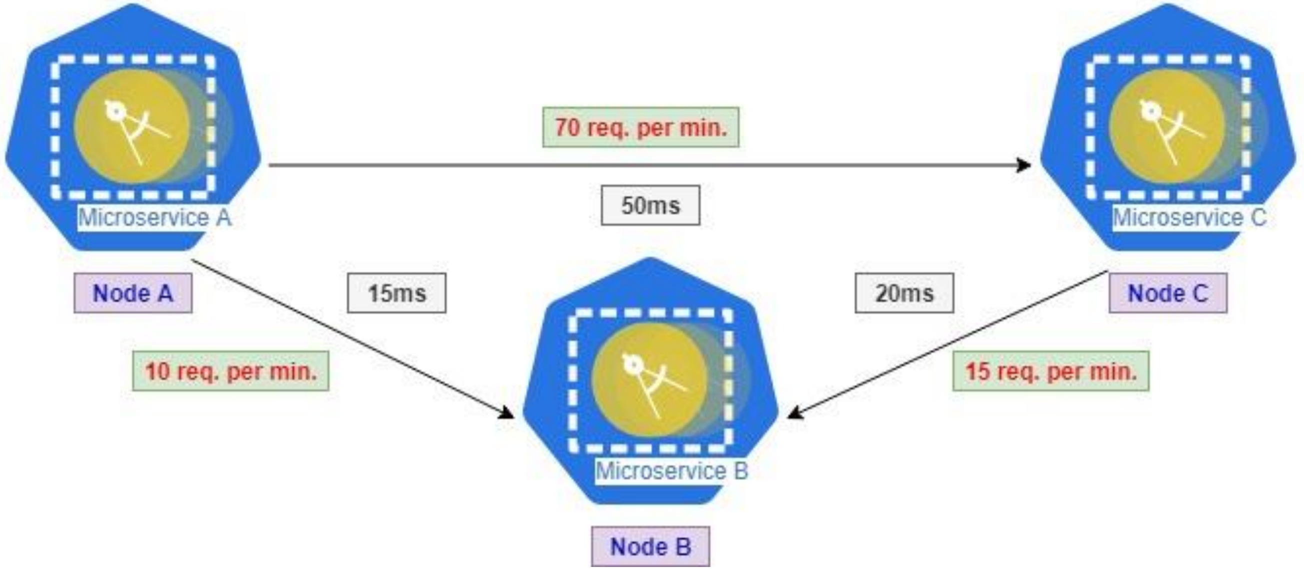
- If all the microservices are deployed in one big Node, we can decrease network latency.

- But then the application will become monolithic. Therefore availability can be reduced and it is one of the main features of Micro-Service architecture



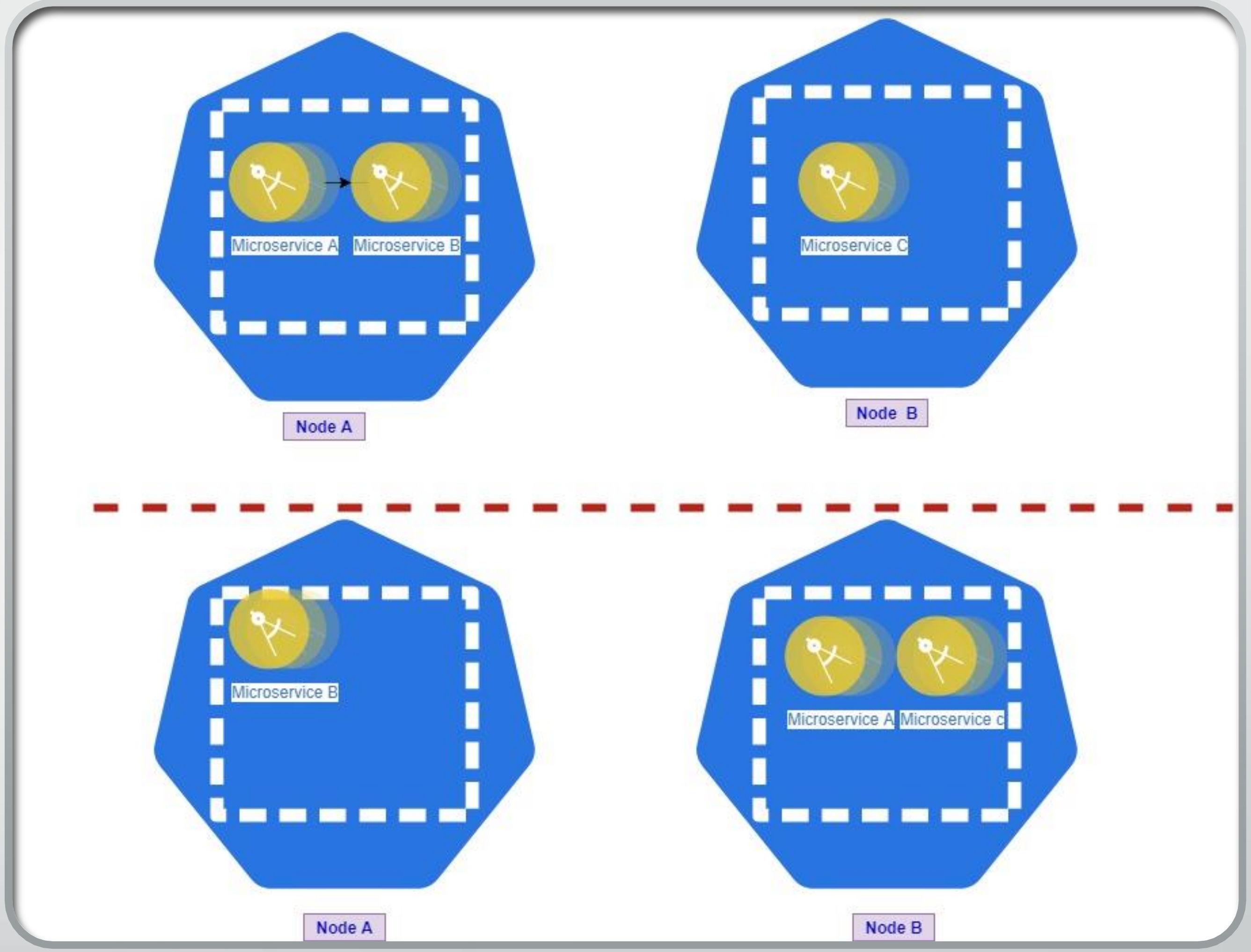
Decrease Overall network latency (scenario 1)

- If the couple of nodes are located in very far, the communication delay time is very low, also if couple of node are located near, communication is very fast.
- Best for multi-region problem



Scenario 2

- Microservice A and C communicate more than microservice A and B.



Related work

There is one research found on optimal deployment strategy[8], it is only concerned about ,

- resource power
- replication
- dependency map

Our research,

- Load prediction
- Resiliency

Objective

- To identify key factors which lead to performance reduction in microservice deployments and come up with an optimal deployment strategy.

Research Questions

HOW SAME REGION NETWORK LATENCY AFFECT ON OVERALL PERFORMANCE ?

HOW DOES ALL THE METRICS AFFECT ON THE OPTIMAL DEPLOYMENT ALGORITHM ?

HOW DOES THE NODE NETWORK COMMUNICATE WITH THE POD NETWORK ?

HOW DOES DIFFERENT SERVICES AFFECT ON ALGORITHM?

Proposed Solution

To solved these previous scenario we develop an optimal deployment algorithm. It ensures the system has optimal availability and low network latency. It controls replication of the microservices and increases overall system performance.

To make this optimization algorithm we should be concerned about,

- Resource power
- Dependency map
- Future loads
- resiliency
- Network latency
- Node resource power
- Replication of microservices

Methodology

GET THE METRIC VALUES FROM DEPENDENCY MAP, LOAD PREDICTIONS, RESILIENCY

CREATE A NODE MAP(NETWORK LATENCY MAP:SOCKPERF (LINUX))

ANALYSIS THE INFORMATION USING OPTIMAL DEPLOYMENT ALGORITHM[6]

SHOW NEXT 24 HOURS DEPLOYMENT MAP AND FUTURE SUGGESTION IN THE UI

Path for the creation of optimal deployment strategy…

- Multi object optimization algorithm
- Identify shortest path between node(Dijkstra algorithm)[7]
- Rank all the metrics
- Identify correct deployment place using the algorithm

Expected Outcomes

- To generate an optimal deployment strategy for a given cluster based on load prediction, dependency analysis and resilience evaluation.
- Next 24 hours deployment map

Automated Deployment

YAML

Discussion and Conclusion

- Tools and frameworks such as Kubernetes provide developer a way in which to deploy and run their microservice applications easily with minimal configuration.
- However, currently, there are no such ways for a developer to evaluate the effectiveness of a particular deployment and identify potential performance issues.
- Furthermore, since identification of these issues require extensive analysis of metrics, it can be difficult for developer to evaluate if a particular microservice meets the expected performance criteria.
- Therefore, a solution should be developed which performs the above-mentioned metric analysis and come up with a model which identifies the potential performance issues such that developers can get the optimal use of their deployed microservices.

Questions ?

Thank you!

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