Disruption-Aware Service Composition and Recovery in Dynamic Networking Environments

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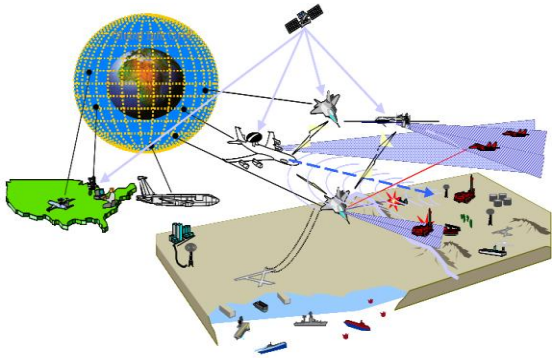
OUTLINE

- Background Introduction
- Service Composition and Recovery Framework
- Service Disruption Model
- Minimum Disruption Service Composition and Recovery Problem Formulation
- Optimal and Heuristic Solutions
- Simulation Study

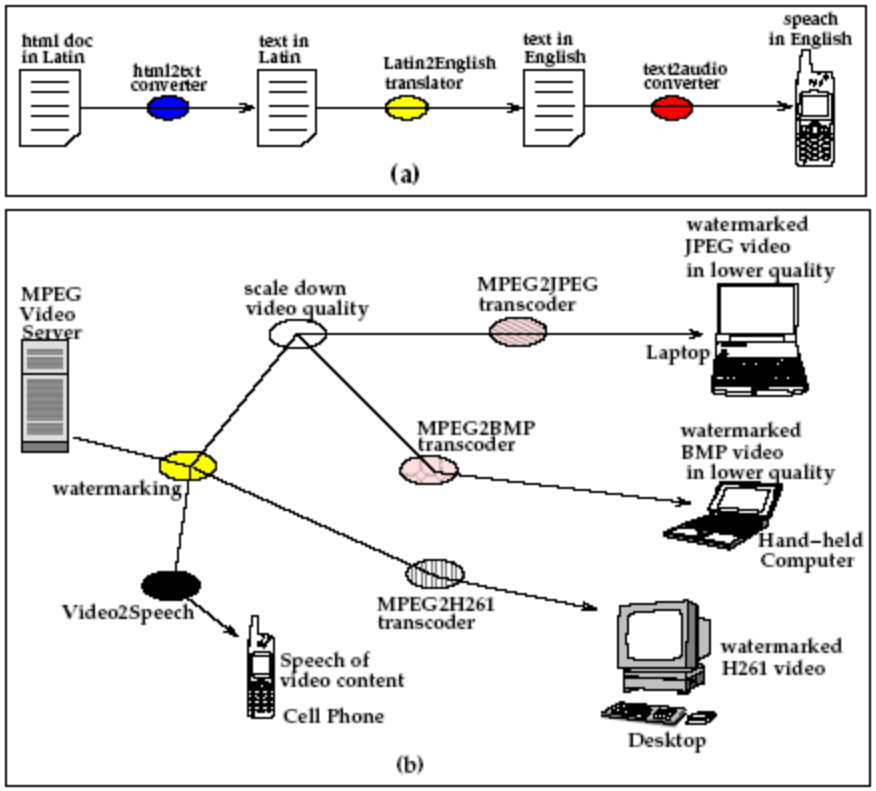
BACKGROUND

- Component-based Software System
  - Building software systems by integrating newly developed and/or previously-existing service components that satisfy diverse application needs
  - To reduce development costs, enable fast system assembling, and reduce the maintenance burden for software systems



BACKGROUND

- Service Composition
  - A technique that integrates loosely coupled distributed service components into a composite service to provide comprehensive functions for end users
  - High flexibility in allowing development and deployment of customized applications from primitive services

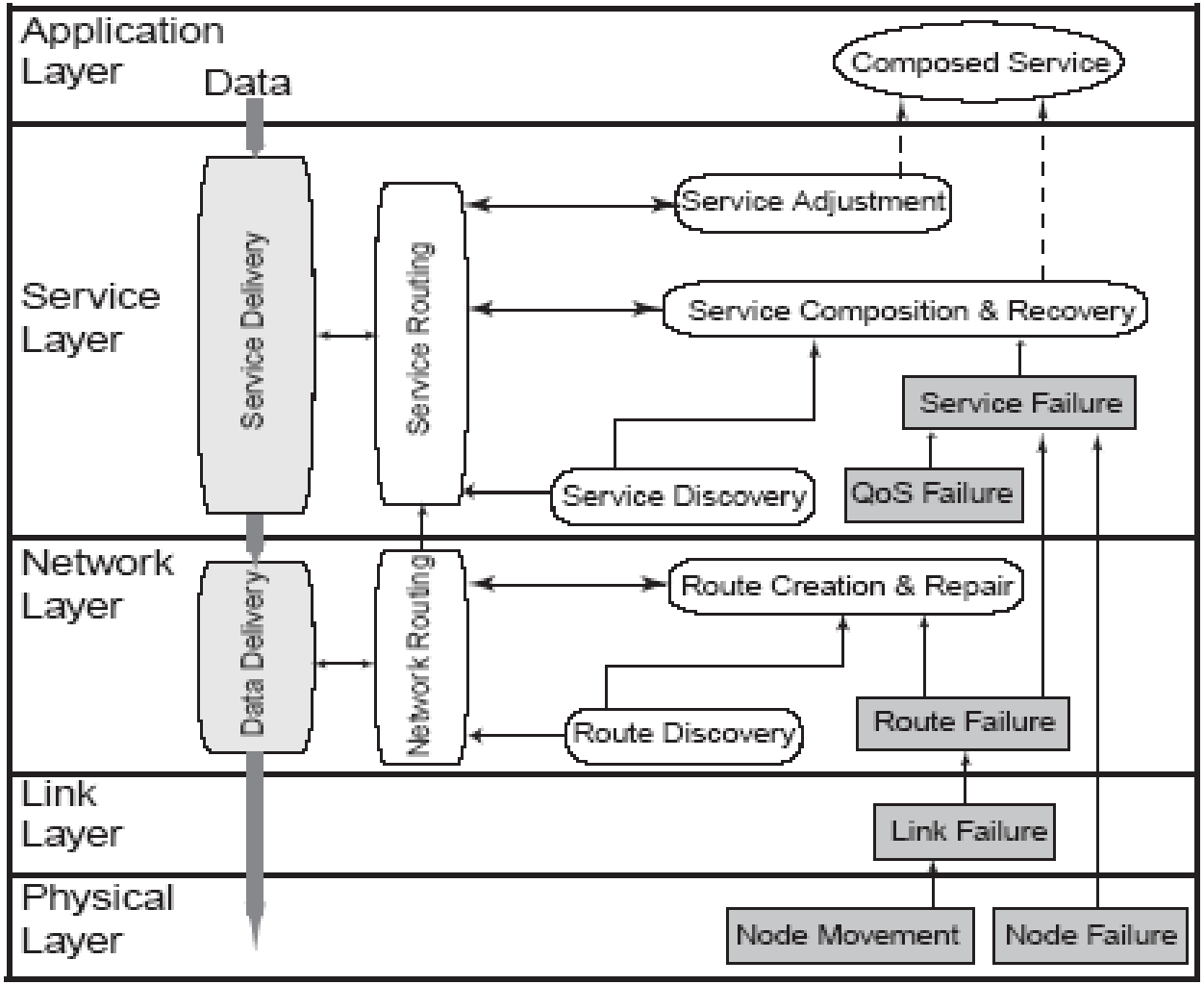


Our work studies Service Composition in Dynamic Networking Environments.

SERVICE COMPOSITION AND RECOVER FRAMEWORK

Service routing, which selects the service components out of many replicas for the service path.

Network routing, which finds the network path that connects the selected service components.



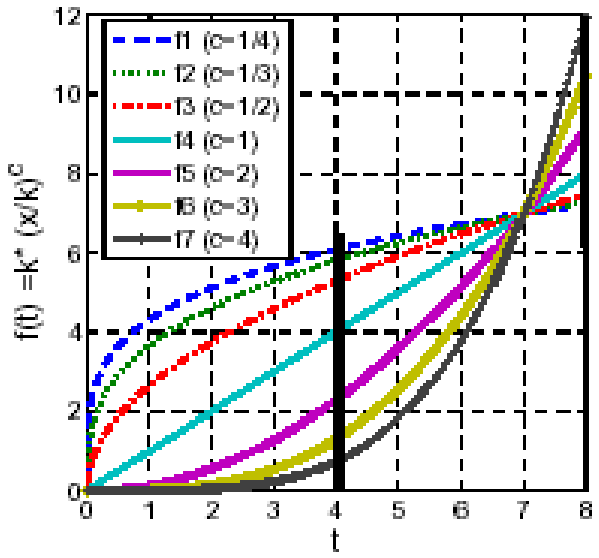
SERVICE DISRUPTION

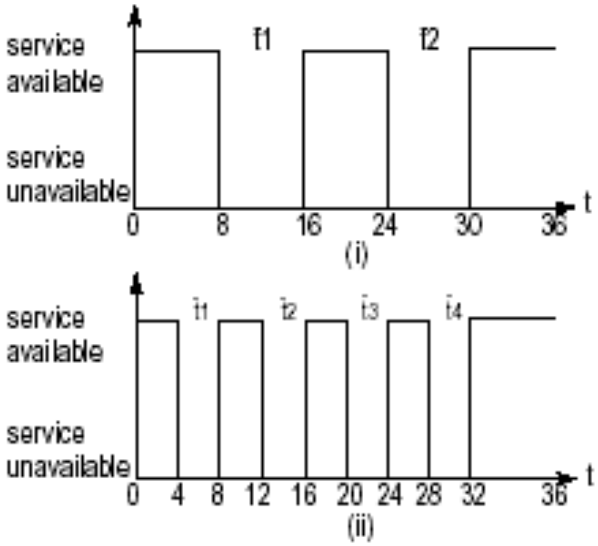
- Service Disruption
  - Due to the dynamic nature of Mobile Ad Hoc Networks, the service is unavailable to end users during the service failure and recovery processes, thereby causing service disruptions.

- Service Availability
  - Service availability is a commonly used metric that quantify the service delivery ability in a system.
  - However, it is insufficient to evaluate the effect of user-perceived disruptions since it can not characterize the impact of disruption frequency or duration.

Quantitatively characterize the impact of user-perceived service disruptions.

SERVICE DISRUPTION MODEL





fi	Fi(4)	Fi(8)	$D_{Process(t)}$	$D_{Process(tt)}$
f1 (convex)	6.0861	7.2376	0.6762	0.4021
f2 (convex)	5.8088	7.3186	0.6454	0.4066
f3 (convex)	5.2915	7.4833	0.5879	0.4157
f4 (linear)	4.0000	8.0000	0.4444	0.4444
f5 (concave)	2.2857	9.1429	0.2540	0.5079
f6 (concave)	1.3061	10.4490	0.1451	0.5805
f7 (concave)	0.7464	11.9417	0.0829	0.6634

Disruption penalty function $F(\bar{t})$

Disruption Index $D = \dfrac{\sum_{i=1}^{q} F(\bar{t}_i)}{T}$

Estimated Disruption duration

$$\begin{aligned} \tilde{t}_k &= \beta \times N_{\pi(t_k)\rightarrow\pi(t_{k+1})} \\ &= \beta \times (N^{\mathcal{N}}_{\pi(t_k)\rightarrow\pi(t_{k+1})} + \alpha N^{\mathcal{S}}_{\pi(t_k)\rightarrow\pi(t_{k+1})}) \end{aligned}$$

Estimated Disruption Index

$$\tilde{D} = \frac{\sum_{k=1}^{l-1} F(\beta \times N_{\pi(t_k)\rightarrow\pi(t_{k+1})})}{T}$$

PROBLEM FORMULATION AND SOLUTIONS

- Minimum Disruption Service Composition and Recovery (**MDSCR**) problem

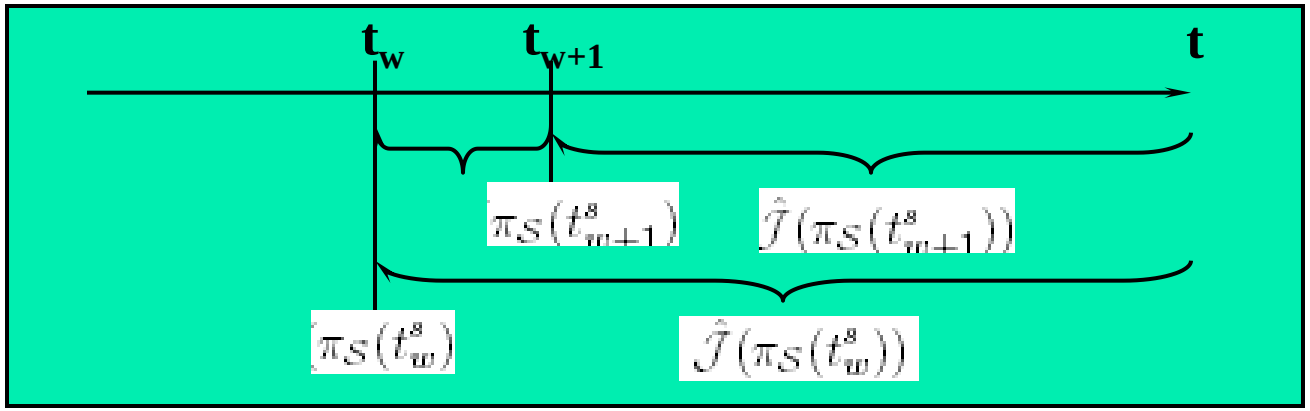
$$\Pi = (\pi(t_1), \pi(t_2), ..., \pi(t_l))$$

$$\text{MDSCR}: \quad \textbf{minimize} \quad \tilde{D}(\Pi)$$

$$\Pi \in \Phi(\mathcal{G})$$

- Solutions to the MDSCR problem
  - **Optimal solution based on dynamic programming**
  - **Heuristic solution based on one-step look-ahead approximation and service link lifetime prediction**

MDSCR HEURISTIC SOLUTION



We present a one-step look-ahead approximation method where ***future disruption index is estimated in the time period until its first service failure***. Let $\hat{J}(\pi_S(t^s_w))$ be the estimated service level minimum disruption index from time instance t_w.

$$\hat{J}(\pi_S(t^s_w)) = \frac{1}{T} F(\beta\alpha N^{S}_{\pi_S(t^s_w)\to\pi_S(t^s_{w+1})}) + \hat{J}(\pi_S(t^s_{w+1}))$$

recovery duration from the failed service path to the new service path

sustainability of the new service path

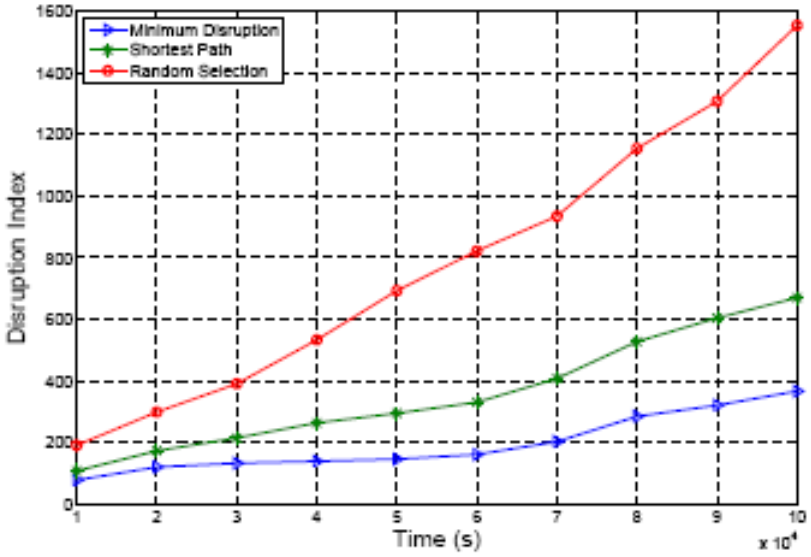
SIMULATION STUDY

- MDSCR algorithm
- SPSCR (shortest path service composition and recovery) algorithm
  - Extension of SP routing algorithm, where the service path with the shortest service link will be selected
- RSSCR (random selection service composition and recovery) algorithm

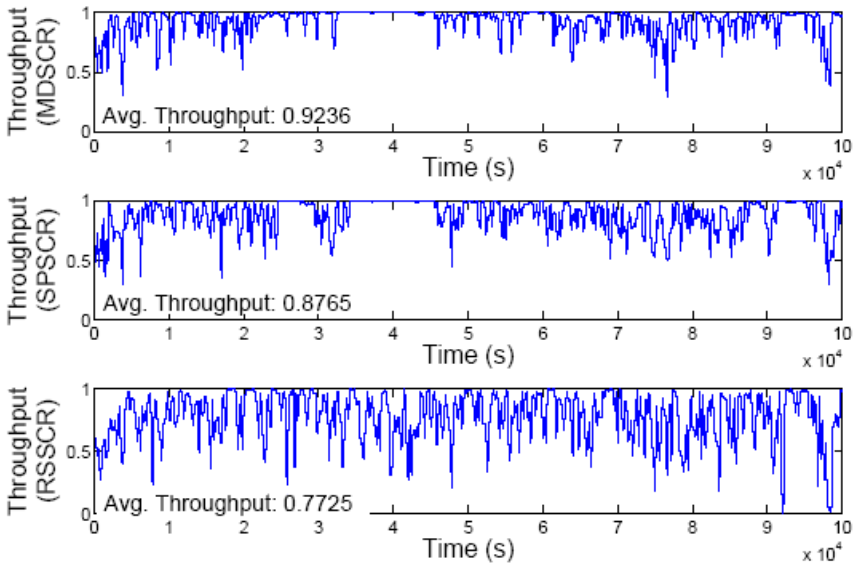
number of nodes	50
network size (m^2)	2000×1000
transmission range (m)	250
maximum speed (m/s)	10
pause time (s)	10
number of components in a service path	4
number of component replica $\lvert\mathcal{N}_k\rvert$	8
service link length requirement H	3
α	10
β	1
disruption penalty function	$F(\bar{t}) = \bar{t}$

Default simulation parameters

SIMULATION STUDY



Disruption comparison with MDSCR, SPSCR, and RSSCR



Throughput comparison with MDSCR, SPSCR, and RSSCR

CONCLUSION

- A theoretical framework for service composition and recovery strategies that characterize the effect of service disruptions
- An optimal solution to MDSCR problem based on dynamic programming techniques and provides important analytical insights for MDSCR heuristic algorithm design
- A simple and effective statistical model based on linear regression that predicts the lifetime of a service link in the presence of highly correlated node and link failures and the network path repairs

THANKS !