A Step Towards Remote Tower Center Deployment: Optimizing Staff Schedules

Billy Josefsson
Tatiana Polishchuk
Valentin Polishchuk
Christiane Schmidt

LINKÖPING UNIVERSITY

TEAMWORK with automation

Remote Tower Center (RTC)

- provides ATS remotely to small airports
- replaces local tower with cameras and sensors
- increases efficiency: HR and ATS costs are split between several airports

Remote Tower Center concept

- in Sweden: LFV + SAAB
- within SESAR Joint Undertaking
- RTC in Sundsvall
  operates 2 airports remotely
  + 5 airports in development

Main question

- How the total workload from several airports is distributed over several controller working positions?

Problem description

Given:

1. Example schedules IFR traffic schedules for 1 day (movement = arrival + departure flights) for five swedish airports

2. Specifications of additional special traffic at these airports (military, school, hospital etc.)

Goal:

Propose optimal assignment of the airports to RTC modules

Constraints

1. Number of airports assigned to one module <= mA
2. Total number of movs within a module <=maxMov
3. One airport assigned to only one module
4. All scheduled traffic from 5 airports is handled
5. All opening hours at 5 airports are covered

Objectives

1. Minimize the number of remote tower modules in use
2. Balance workload between the modules
3. Minimize assignment switches

Experimental evaluation

1. Data analysis of example schedules and extra traffic specifications for 2 example weeks in 2016 for 5 Swedish airports

-> extract 1-day data samples (the days with highest traffic)

2. Solved MIP using AMPL CPLEX 12.6 solver

-> example solutions with different objectives

3. Post-processing: avoid potential conflicts in schedules within one module

4. Include special airport traffic

5. Residual system capacity estimation

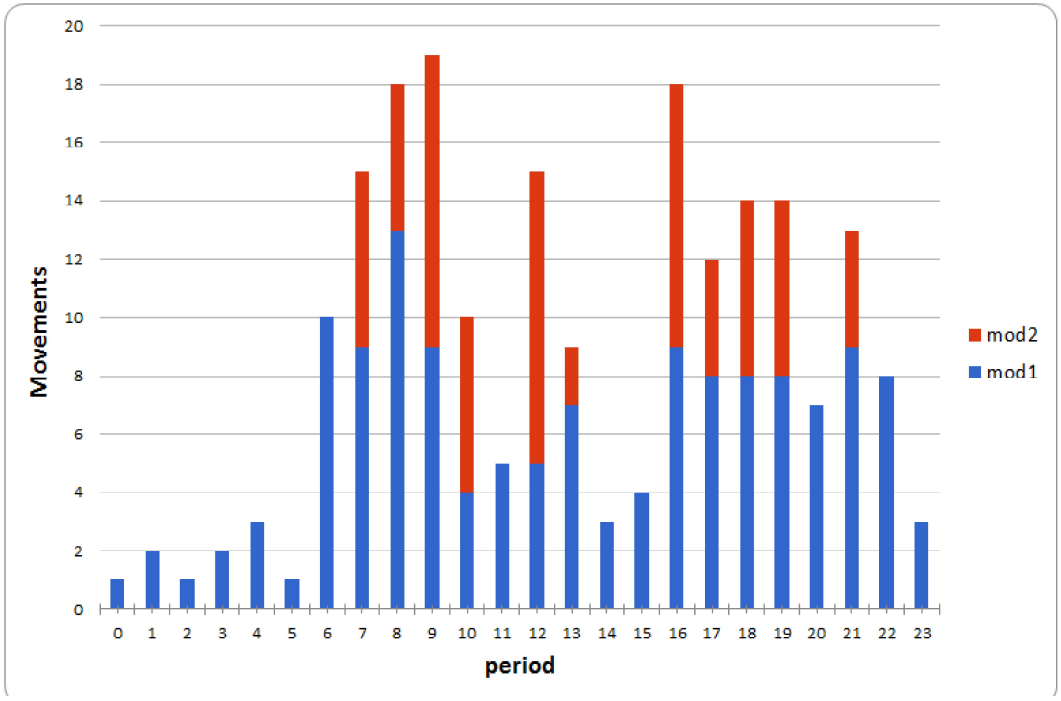
Initial assumptions (conservative)

1. Max # airdromes/module = 2 (relaxed for the estimation of upper bound)
2. Max movs per module / hour= 10 (if >10 movements are initially scheduled at some airport, reduce to 10 wlog)

Minimizing the number of modules in use

Schema 1: lower bound (>2 airs allowed per module)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP1	0	0	0	0	0	0	1	0	0	0	0	0	2	2	0	0	1	1	0	0	0	0	0	1
AP2	1	2	1	1	2	1	3	9	10	6	4	3	3	5	2	0	5	6	5	7	2	6	4	1
AP3	0	0	0	1	1	0	0	2	1	6	3	1	5	2	0	3	6	3	4	4	4	2	2	1
AP4	0	0	0	0	0	0	3	2	4	3	2	1	2	2	1	0	3	1	3	1	0	3	1	0
AP5	0	0	0	0	0	0	3	2	0	4	1	0	3	0	0	1	3	1	2	2	1	2	1	0

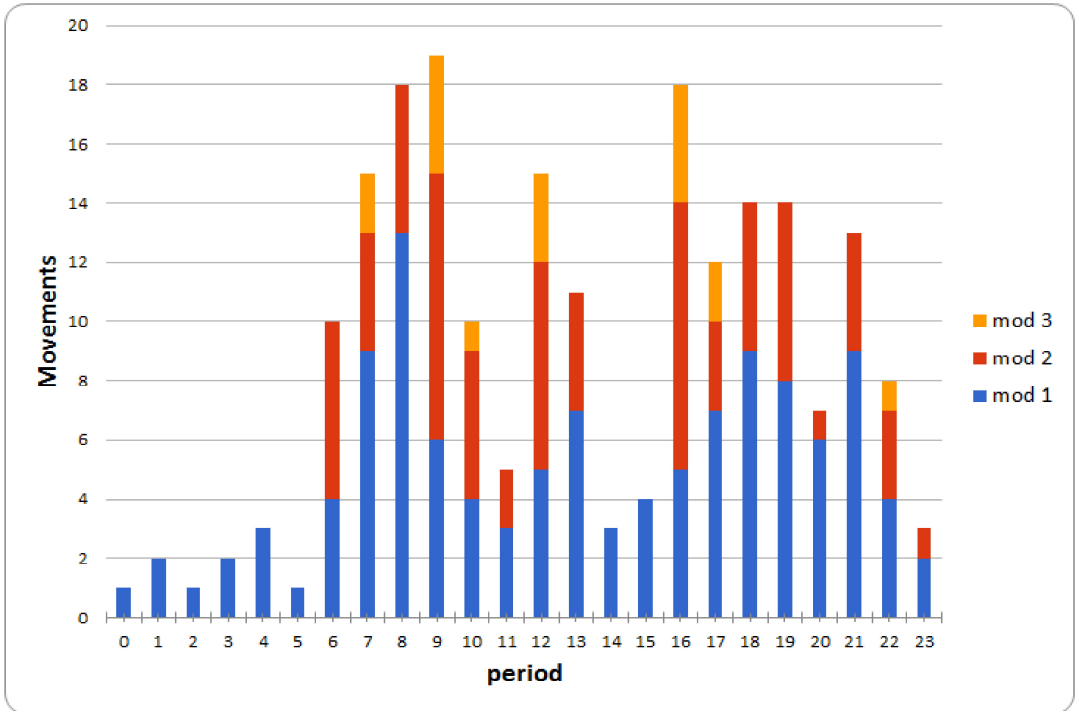


2 modules suffice!

Minimizing the number of modules in use

Schema 2: <=2 airs per module

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP1	0	0	0	0	0	0	1	0	0	0	0	0	2	2	0	0	1	1	0	0	0	0	0	1
AP2	1	2	1	1	2	1	3	9	10	6	4	3	3	5	2	0	5	6	5	7	2	6	4	1
AP3	0	0	0	1	1	0	0	2	1	6	3	1	5	2	0	3	6	3	4	4	4	2	2	1
AP4	0	0	0	0	0	0	3	2	4	3	2	1	2	2	1	0	3	1	3	1	0	3	1	0
AP5	0	0	0	0	0	0	3	2	0	4	1	0	3	0	0	1	3	1	2	2	1	2	1	0

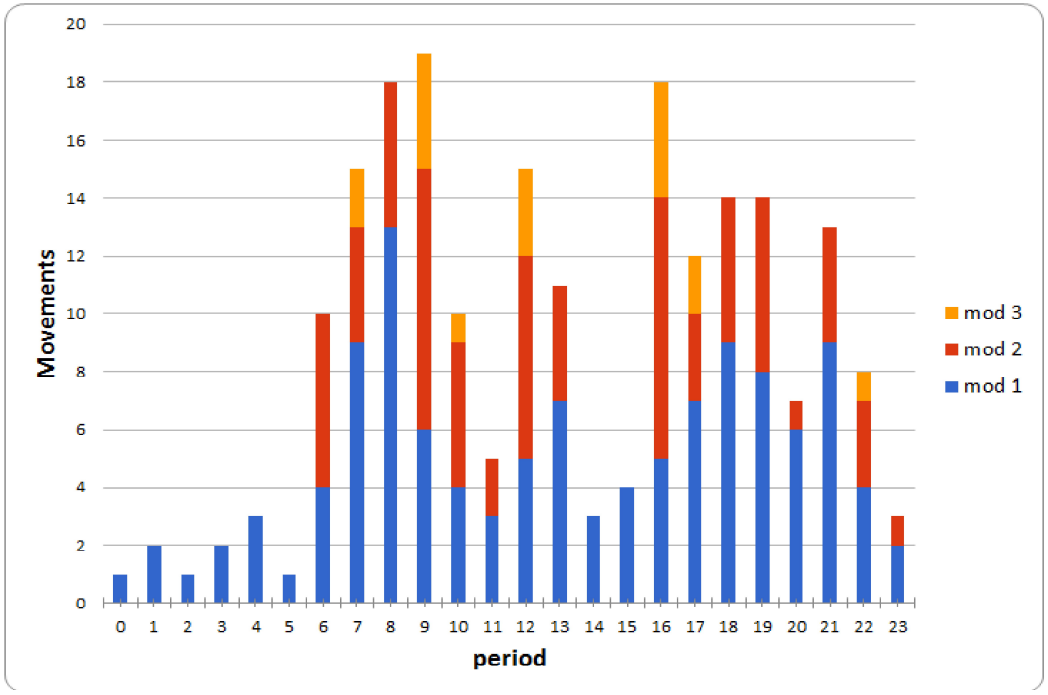


3 modules are needed

Balancing the load

Schema 2 – not balanced in the number of movements per module

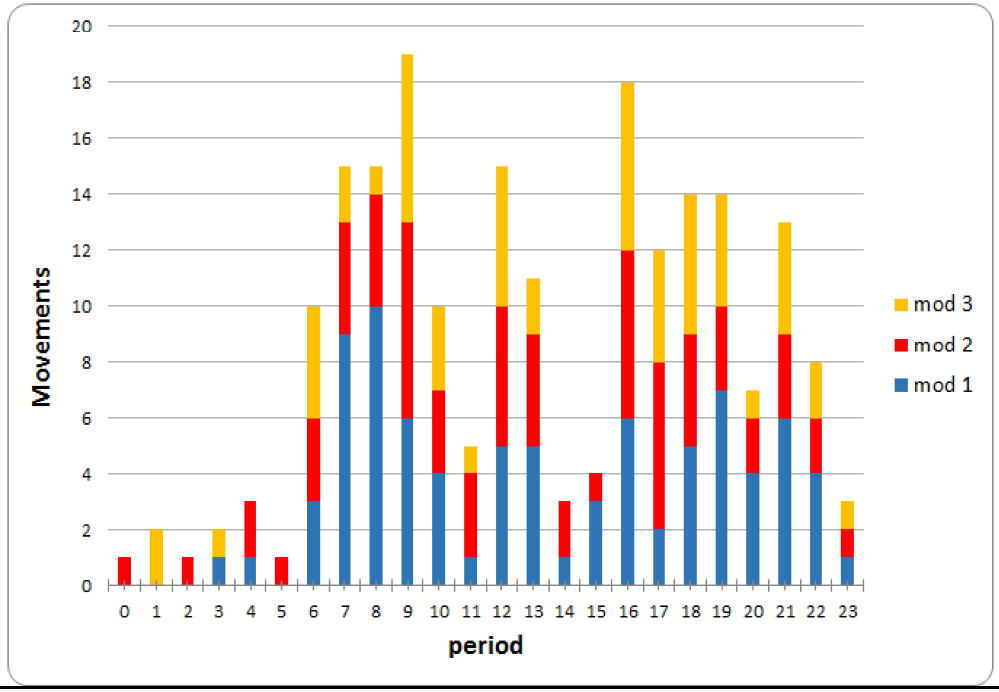
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP1	0	0	0	0	0	0	1	0	0	0	0	0	2	2	0	0	1	1	0	0	0	0	0	1
AP2	1	2	1	1	2	1	3	9	10	6	4	3	3	5	2	0	5	6	5	7	2	6	4	1
AP3	0	0	0	1	1	0	0	2	1	6	3	1	5	2	0	3	6	3	4	4	4	2	2	1
AP4	0	0	0	0	0	0	3	2	4	3	2	1	2	2	1	0	3	1	3	1	0	3	1	0
AP5	0	0	0	0	0	0	3	2	0	4	1	0	3	0	0	1	3	1	2	2	1	2	1	0



Balancing the load

Schema 3 – better balanced -> more assignment switches

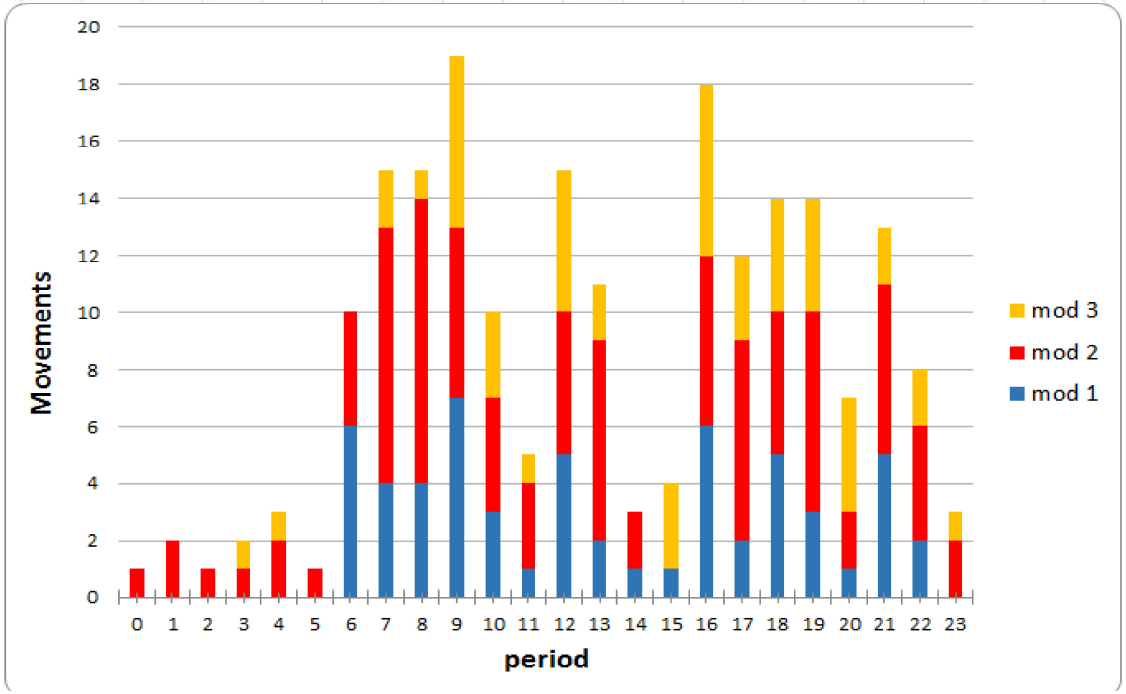
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP1	0	0	0	0	0	0	1	0	0	0	0	0	2	2	0	0	1	1	0	0	0	0	0	1
AP2	1	2	1	1	2	1	3	9	10	6	4	3	3	5	2	0	5	6	5	7	2	6	4	1
AP3	0	0	0	1	1	0	0	2	1	6	3	1	5	2	0	3	6	3	4	4	4	2	2	1
AP4	0	0	0	0	0	0	3	2	4	3	2	1	2	2	1	0	3	1	3	1	0	3	1	0
AP5	0	0	0	0	0	0	3	2	0	4	1	0	3	0	0	1	3	1	2	2	1	2	1	0



Minimize the number of switches

Schema 4 – less assignment switches -> not balanced

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP1	0	0	0	0	0	0	1	0	0	0	0	0	2	2	0	0	1	1	0	0	0	0	0	1
AP2	1	2	1	1	2	1	3	9	10	6	4	3	3	5	2	0	5	6	5	7	2	6	4	1
AP3	0	0	0	1	1	0	0	2	1	6	3	1	5	2	0	3	6	3	4	4	4	2	2	1
AP4	0	0	0	0	0	0	3	2	4	3	2	1	2	2	1	0	3	1	3	1	0	3	1	0
AP5	0	0	0	0	0	0	3	2	0	4	1	0	3	0	0	1	3	1	2	2	1	2	1	0



Observations

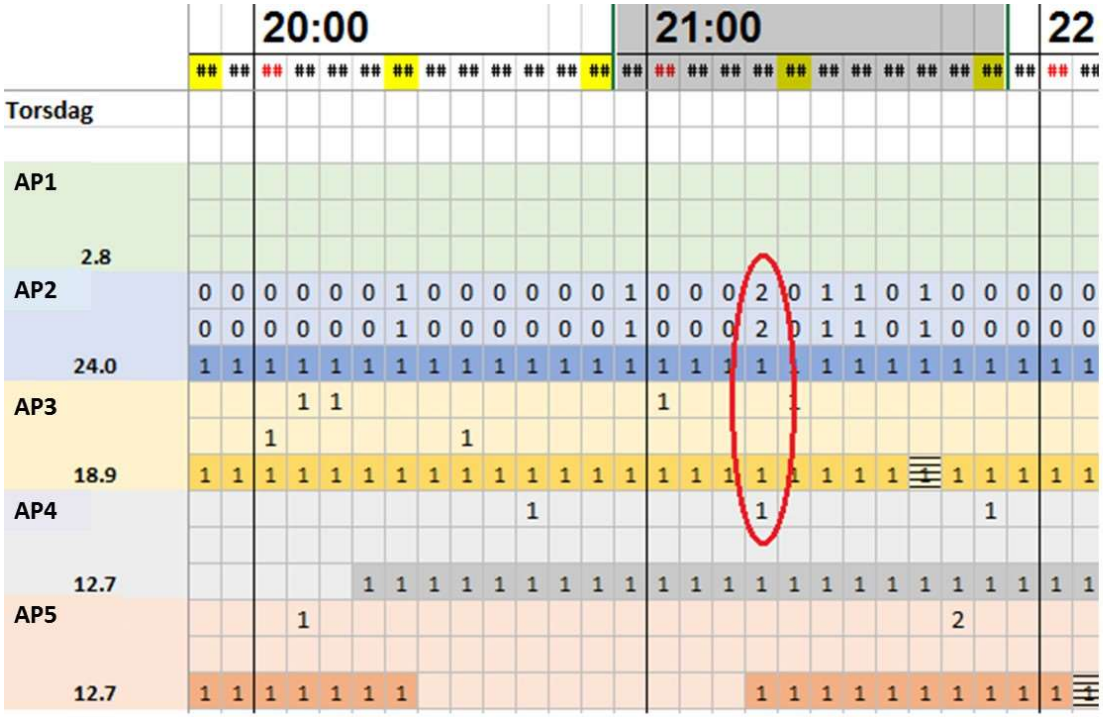
We observed clear trade-offs between the 3 objectives:

- Minimize the number of modules in use
- Improve balancing
- Minimize switches

What can we do?

- Place priorities according to current needs
  (e.g. balancing may have lower priority in the begining)
- Combine solutions (e.g.- first find the min number of modules, then apply the other 2 objectives)

Post-processing: avoid potential conflicts



Conflict:
>=3 movs / 5 min

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP2 self									8:10	9:20				13:30				17:20				21:15		
AP2_AP5										9:20														
AP2_AP3																	16:20							
AP2_AP4																						21:15		

Post-processing: avoid potential conflicts (cont.)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP2 self									8:10	9:20				13:30				17:20				21:15		
AP2_AP5										9:20														
AP2_AP3																	16:20							
AP2_AP4																						21:15		

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP1	0	0	0	0	0	0	1	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	1	0
AP2	0	6	2	0	4	2	1	0	8	4	2	2	2	10	0	4	2	8	6	2	4	10	4	0
AP3	0	3	0	2	2	0	3	5	1	7	3	1	6	1	0	3	5	3	4	5	4	2	1	1
AP4	0	0	0	0	0	0	1	2	4	2	1	1	3	3	2	0	4	1	4	2	1	2	0	0
AP5	0	0	0	0	0	0	3	1	2	4	1	0	4	0	0	2	4	3	2	2	1	2	1	0

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP1	0	0	0	0	0	0	1	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	1	0
AP2	0	6	2	0	4	2	1	0	8	4	2	2	2	10	0	4	2	8	6	2	4	10	4	0
AP3	0	3	0	2	2	0	3	5	1	7	3	1	6	1	0	3	5	3	4	5	4	2	1	1
AP4	0	0	0	0	0	0	1	2	4	2	1	1	3	3	2	0	4	1	4	2	1	2	0	0
AP5	0	0	0	0	0	0	3	1	2	4	1	0	4	0	0	2	4	3	2	2	1	2	1	0

Changes: re-assign ESMS to a separate module during periods 8 and 9

Analysis of non-scheduled (VFR) traffic / day

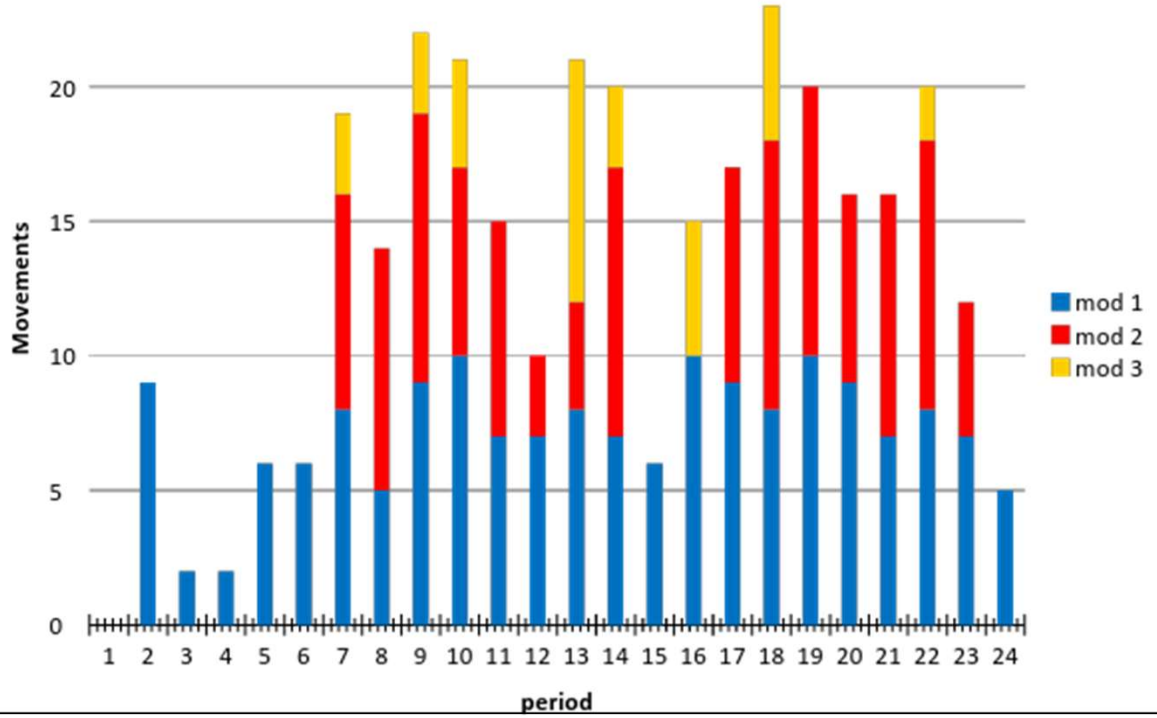
		norm	worst case
kiruna	FM	3	10
	HKP	5	17
	Skol	1	3
	Special	2	5
	Övrigt	1	5
sturup	FM	1	3
	HKP	1	4
	Skol	5	20
	Special	14	60
	Övrigt	2	10
umeå	FM		
	HKP	4	12
	Skol	2	8
	Special	4	10
	Övrigt	4	4
visby	FM	6	125
	HKP	7	21
	Skol	4	10
	Special	2	10
	Övrigt		
Östersun	FM	8	20
	HKP	8	20
	Skol	3	8
	Special	4	12

3 types of model runs (modes)

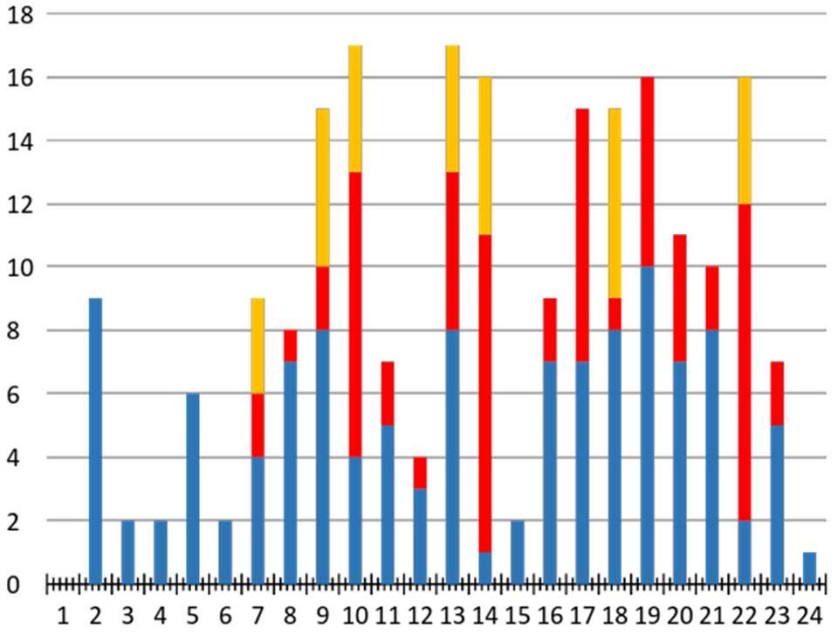
1. Only regular scheduled traffic (no extra traffic)
2. Add moderate amount of extra traffic (normal)
3. Worst-case scenario with MAX load

Extra traffic in normal operation (schema 5)

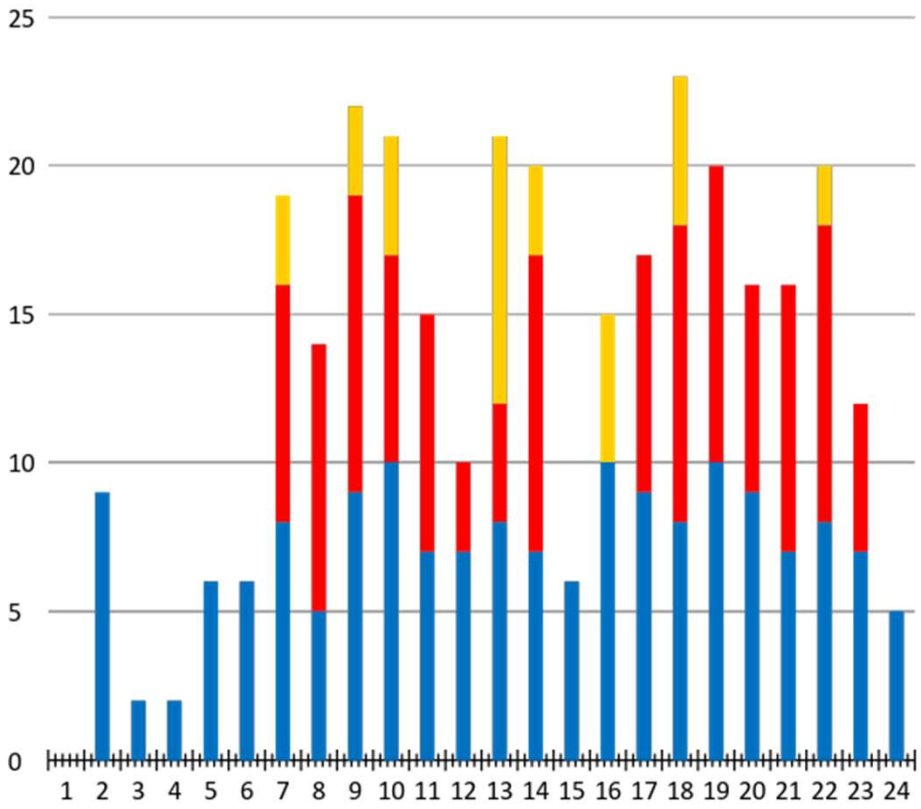
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP1	0	0	0	0	0	2	3	0	0	0	0	0	4	4	0	0	0	0	0	0	0	0	3	2
AP2	0	6	2	0	4	4	3	2	10	6	4	4	2	10	2	6	4	10	6	3	4	10	4	0
AP3	0	3	0	2	2	0	5	5	3	7	5	3	6	3	0	5	5	5	6	5	6	4	3	3
AP4	0	0	0	0	0	0	3	4	5	4	3	3	3	3	4	0	4	3	4	4	3	2	0	0
AP5	0	0	0	0	0	0	5	3	4	4	3	0	6	0	0	4	4	5	4	4	3	4	2	0



Scheduled traffic vs. plus extra traffic (norm.)



Scheduled



Plus extra traffic (norm.)

Moderate amount of extra traffic added - 3 modules still suffice

Worst case: MAX load operation (Schema 6)

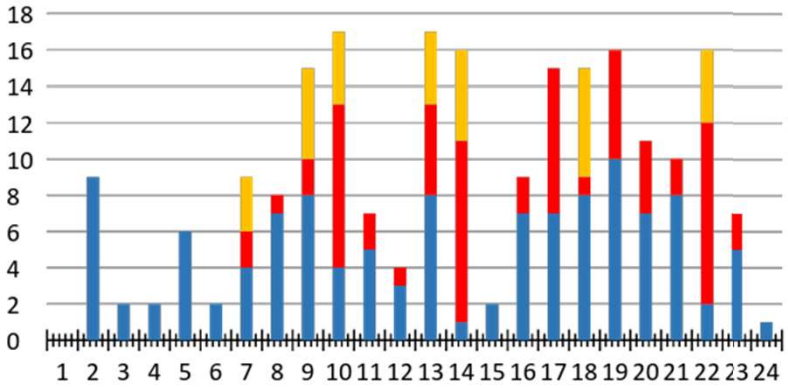
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP1	0	0	0	0	0	6	10	0	0	0	0	0	5	5	0	0	0	0	0	0	0	0	10	10
AP2	6	8	8	6	8	6	7	6	8	8	8	8	8	10	6	9	7	8	9	6	6	10	8	6
AP3	0	4	0	4	2	0	3	5	5	7	6	5	6	6	0	6	5	6	6	5	6	3	3	3
AP4	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	0	10	10	10	10	10	10	0	0
AP5	0	0	0	0	0	0	7	5	6	8	6	0	8	0	0	6	7	7	6	6	7	7	6	0

Problem: max extra traffic may not fit into the schedule

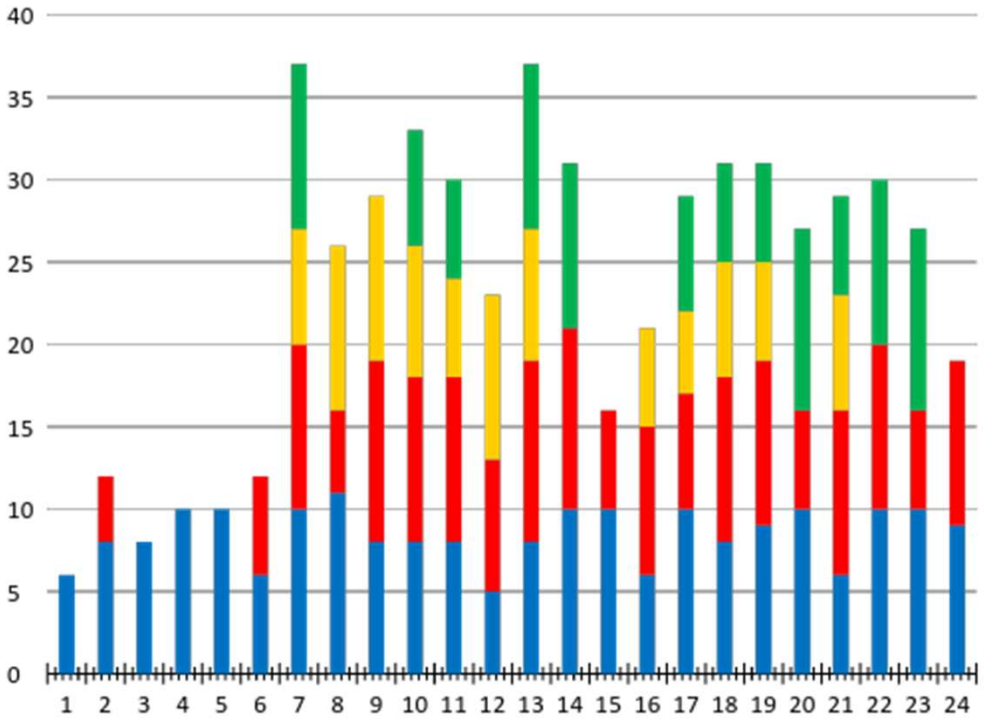
Possible solutions:

1. Extend airdrome's open hours in some special situations (e.g. max military traffic at AP4)
2. Relax our conservative assumptions: Max mov / hour/module > 11? > 12?

Scheduled traffic vs. MAX extra traffic



Scheduled



MAX extra traffic

Residual capacity of RTC with 3 modules

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	*sum*
AP1						10	9						8	8									9	10	54
AP2	10	4	8	10	6	8	9		2	6	8	8	8	0		6	8	2	4	8	6	0	6	10	137
AP3	10	7		8	8		7	5	9	3	7	9	4	9		7	5	7	6	5	6	8	9	9	148
AP4							9	8	6	8	9	9	7	7	8		6	9	6	8	9	8			117
AP5							7	9	8	6	9		6			8	6	7	8	8	9	8	9		108

Residual = Max Movs (10) – scheduled movs

Airport	Residual	MODE 2 (normal)	MODE 3 (worst-case)
AP1	54	12	40
AP2	137	23	97
AP3	148	24	34
AP4	117	19	166
AP5	108	23	60

Problem at AP4: max extra traffic exceeds the residual capacity

Conclusions

- ✓ Optimization framework for future staff planning at RTC is created
- ✓ Example solutions (schemes) proposed
- ✓ Provided new evidence of RTC efficiency
- ✓ Subject to reality checks and discussions

Future work

- ✓ Deeper EUROCONTROL data analysis for the year 2016
- ✓ Refine the model to reflect seasonal changes
- ✓ Shift focus towards actual ATCO shifts
- ✓ Include ground traffic into consideration
- ✓ Re-consider the workload definition

Questions?

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Thank you!