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Experience Solving the RTO Unit Commitment Test System

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Motivation – Adapt algorithm successfully used with FTR to solve Unit Commitment problems

- Parallel Adaptive Dynamical System (PADS) Algorithm has several advantages
  - Scalability—scales roughly as the square of the problem size
  - Parallelizable—key operation is a (constant) matrix times vector operation
    - A constant (sparse) matrix simplifies load balancing
    - Maintains numerical precision
    - Time per iteration is constant—no backfilling of matrix
- Algorithm is LP solver with limits. Can it be adapted to more generalized LP problems?
  - LP solver within the Branch-and-Bound portion of a MIP solver
  - Test against FERC RTO Unit Commitment Test System

PNNL Algorithm –
Parallel Adaptive Dynamical System (PADS)

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- Transform LP into coupled set of non-linear dynamical equations
- Dynamical system may converge to stable states which are solutions of primal and dual LP problems respectively

Primal

maximize $c^T x$
subject to $Ax \leq b$ and $x \geq 0$

Dual

minimize $b^T y$
subject to $A^T y \geq c$ and $y \geq 0$

Non-linear Dynamical System

$$\frac{dx}{dt} = k_1\left(c - A^T\left(y + k\frac{dy}{dt}\right)\right)$$
$$\frac{dy}{dt} = k_2\left(-b + A\left(x + k\frac{dx}{dt}\right)\right)$$

$$k_1 = \frac{K}{i} \qquad i = 1, 2, \dots M \qquad k_2 = \frac{1}{k_1}$$

- Kernel is a pair of easily parallelized matrix-vector operations: scale as square of problem size (constraints x variables)
- K, M, and dt are input (tuning) parameters

Optimization Infrastructure

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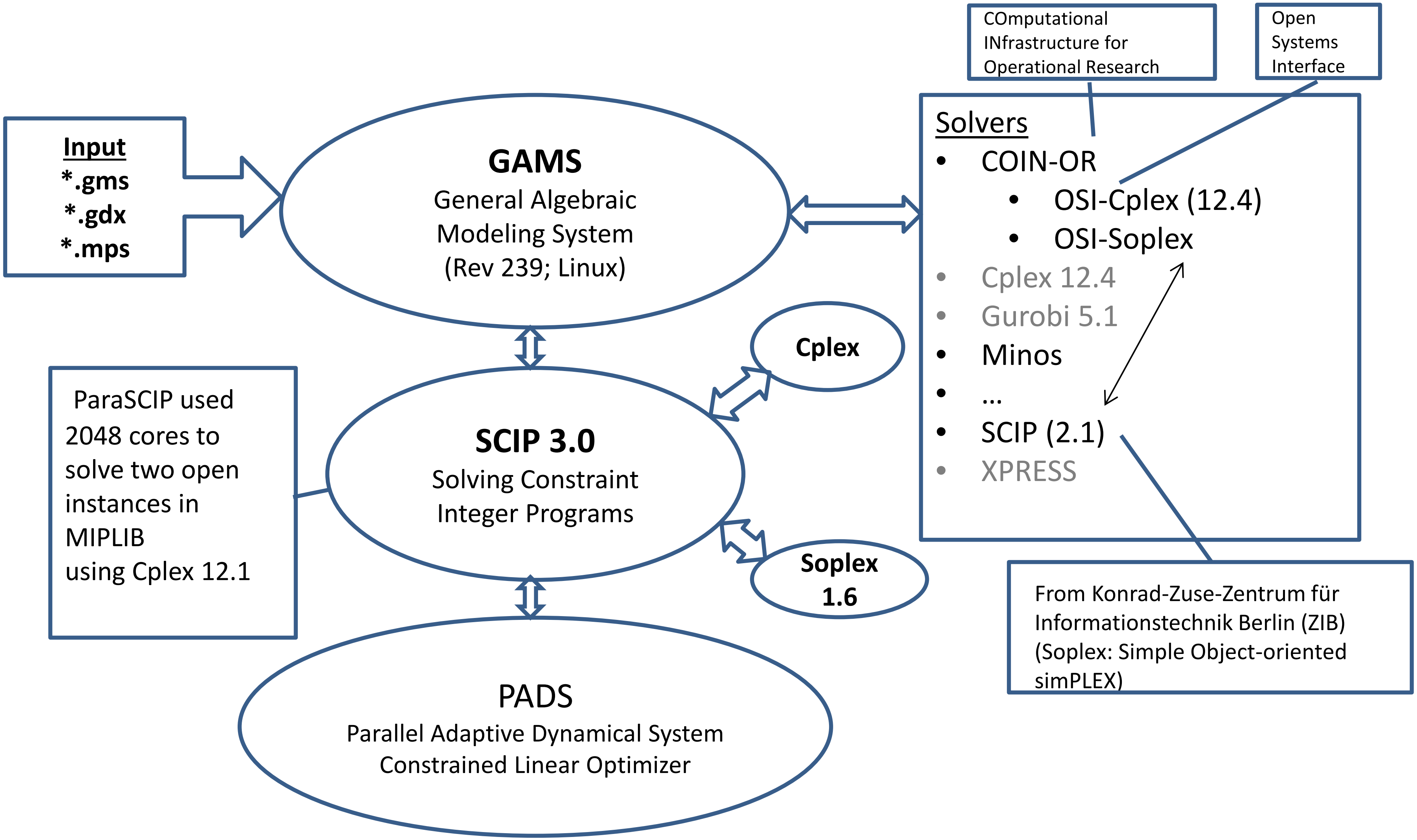
- Use GAMS as modeling language
  - FERC RTO Unit Commitment Test System has GAMS input
  - GAMS uses many solvers including CPLEX and SCIP
  - Using modified version of SCIP/PADS

- For MIP, adapt PADS for use with SCIP (Solving Constraint Integer Programs)
  - Developed at Konrad-Zuse-Zentrum für Informationtechnik Berlin
  - Parallel extension (ParaSCIP) used 2048 cores to solve two open instances in MIPLIB using CPLEX 12.1

Optimization Infrastructure Diagram



RTO Day Ahead Unit Commitment Results

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Summer all lines *4853.gdx							initial	1,410,826	2,533,152	17,487,208			
option mip	**version**	**gap tol**	**MIP/primal**	**Best/dual**	**gap**	**gap %**	**presolv sec**	**const (row)**	**var (col)**	**non-zero**	**MIP sec**	**relax sec**	**elapsed**
gurobi (FERC)	4.0	5%	18,017,325	17,276,545	740,780	4.11%	2,476				2,777		1:27:33
osicplex	12.4	5%	17,129,590	17,107,820	21,770	0.13%	37	252,980	669,067	3,289,228	595	77	0:12:53
osicplex	12.4	0.1%	17,119,760	17,107,820	11,940	0.07%	42	252,980	669,067	3,289,228	720	85	0:14:43
osicplex	12.5	5%	17,130,490	17,108,030		0.13%	4	252,980	669,067	3,289,228	393	69	0:09:09
scip	2.2.1	5%	17,280,971	16,599,749	681,222	4.10%	1,905	278,550	1,006,444		328,735		91:26:37
scip	3.0	5%	17,253,230	16,639,225	614,005	3.69%	1,476	277,536	1,005,450	9,055,811	110,957		31:10:12

Summer subset of lines *9999.gdx							initial	1,574,612	2,618,929	5,740,945			
option mip	**version**	**gap tol**	**MIP/primal**	**Best/dual**	**gap**	**gap %**	**presolv sec**	**const (row)**	**var (col)**	**non-zero**	**MIP sec**	**relax sec**	**elapsed**
gurobi (FERC)	4.0	5%	17,977,310	17,225,488	751,822	4.18%	502				674		0:19:36
osicplex	12.4	5%	16,252,850	15,545,160	707,690	4.55%	22	155,122	150,133	704,391	43	16	0:01:48
osicplex	12.4	1%	15,948,720	15,946,900	1,820	0.01%	22	155,122	150,133	704,391	87	16	0:02:23
osicplex	12.5	5%	16,243,080	15,545,160	697,920	4.49%	1	155,122	150,133	704,391	20	14	0:01:07
scip	2.2.1	5%	16,135,578	15,538,193	597,385	3.84%	439	270,779	971,104		50,019		13:55:58
scip	3.0	5%	16,130,088	15,544,806	585,282	3.77%	3,972	261,938	962,765	2,848,228	7,349		2:04:46

Winter subset *0000.gdx							initial	1,247,590	2,385,553	4,935,569			
option mip	**version**	**gap tol**	**MIP/primal**	**Best/dual**	**gap**	**gap %**	**presolv sec**	**const (row)**	**var (col)**	**non-zero**	**MIP sec**	**relax sec**	**elapsed**
gurobi (FERC)	4.0	5%	25,085,574	24,666,532	419,042	1.73%	530				123		0:10:53
osicplex	12.4	5%	24,697,480	24,507,430	190,050	0.78%	21	162,521	163,271	751,862	53	27	0:01:55
osicplex	12.5	5%	24,880,090	24,507,430	372,660	1.52%	1	162,521	163,271	751,862	44	21	0:01:06
scip	2.2.1	5%	24,708,238	24,507,361	200,878	0.82%	239	279,407	805,800		8,428		2:22:05
scip	3.0	5%	24,705,720	24,507,361	198,359	0.81%	3,659	271,413	798,478	2,545,582	2,045		1:36:02

FERC results run on 2.4 GHz Intel Xeon E7458

PNNL results run on 2.1 GHz AMD Opteron 6272; 2.27 GHz Intel Xeon 5520

$onUNDF added to .gms file for all lines case

PADS Results

- Very sensitive to form of input matrix
  - FTR is only large problem to produce nearly converged results
  - FTR input from GAMS/SCIP (with or without presolve) dramatically slows convergence
  - UC test system diverges
- Looking at Chris DeMarco's power system case study examples
  - Dropped quadratic cost terms so LP can be used instead of QP
  - Using Matpower to test improvement strategies
- Existing cases likely too small to show beneficial results even if PADS problems can be solved.