NC State University
ECE Department ECE 720 W. Rhett Davis

Homework #3 Solution

Problem 1)
It's easiest to do this problem by first computing the connectivity matrix **C**, in which each element $c_{a,b}$ is equal to the edge weights in the graph= $4/(n^2\text{-mod}(n,2))$, where n is the number of connections on each net. This is somewhat confusing for $c_{1,2}$ and $c_{1,4}$, because there are two nets connecting these instances. In these cases, use the sum of the weights for each net.

Vertex	1	2	3	4	5	6	7	8	9	10
1	0	1.25	0.25	0.5	0.25	0	0	0	0.25	0
2	1.25	0	0	0.25	0.25	0.5	0	0	0	0.5
3	0.25	0	0	0.25	0	0	0	0	0.25	0
4	0.5	0.25	0.25	0	0.25	0	0	1	0.25	0
5	0.25	0.25	0	0.25	0	1	0	1	1	0
6	0	0.5	0	0	1	0	0	0	0	0.5
7	0	0	0	0	0	0	0	1	0	0
8	0	0	0	1	1	0	1	0	0	0
9	0.25	0	0.25	0.25	1	0	0	0	0	0
10	0	0.5	0	0	0	0.5	0	0	0	0

(a)
The two partitions are A = {1,2,3,4,5} & B = {6,7,8,9,10}
$T = c_{1,9}+c_{2,6}+c_{2,10}+c_{3,9}+c_{4,8}+c_{4,9}+c_{5,6}+c_{5,8}+c_{5,9}$
$= 0.25 + 0.5 + 0.5 + 0.25 + 1 + 0.25 + 1 + 1 + 1$
$= 5.75$

(b)
$W_a = W_1(\text{XOR})+W_2(\text{FF})+W_3(\text{XOR})+W_4(\text{AND})+W_5(\text{MUX}) = 47$
$W_b = W_6(\text{FF})+W_7(\text{AND})+W_8(\text{OR})+W_9(\text{AND})+W_{10}(\text{AND}) = 39$
$W_b < W_a < 48$, this partition is admissible

(c)
$D_2 = E_2 - I_2 = c_{2,6}+c_{2,10}-c_{1,2}-c_{2,4}-c_{2,5} = 0.5 + 0.5 - 1.25 - 0.25 - 0.25 = -0.75$
Since node 7 connects to node 8 only, we can effectively ignore the cost of node 7 if we move it with node 8
$D_{7,8} = D_8 = E_8 - I_8 = c_{8,4}+c_{8,5} = 2$
Gain = $g = D_8+D_2-2\,c_{2,8} = 2 - 0.75 = 1.25$

(d)
$W_a = W_1(\text{XOR})+W_3(\text{XOR})+W_4(\text{AND})+W_5(\text{MUX})+W_7(\text{AND})+W_8(\text{OR}) = 38$
$W_b = W_2(\text{FF})+W_6(\text{FF})+W_9(\text{AND})+W_{10}(\text{AND}) = 48$
This partition is admissible

(e)
Acceptable partitions must have T<4.5. Some acceptable partitions are are given below:

A	B	T	w_a	w_b
{1,3,4,5,7,8,9}	{2,6,10}	$c_{1,2}+c_{2,4}+c_{2,5}+c_{5,6}=2.75$	43	43
{1,2,4,7,8}	{3,5,6,9,10}	$c_{1,3}+c_{1,5}+c_{1,9}+c_{2,5}+c_{2,6}+c_{2,10}+c_{3,4}+c_{4,5}+c_{4,9}+c_{5,8}=3.75$	42	44
{1,2,3,4,10}	{5,6,7,8,9}	$c_{1,5}+c_{1,9}+c_{2,6}+c_{3,9}+c_{4,5}+c_{4,8}+c_{4,9}+c_{6,10}=3.25$	45	41
{1,2,3,4,9}	{5,6,7,8,10}	$c_{1,5}+c_{2,5}+c_{4,5}+c_{9,5}+c_{2,6}+c_{4,8}+c2,10=3.75$	45	41

Problem 2)

Global wires should be assumed, since this will give the minimum delay.

$$t_{p1} = 0.69(548)(0.61)(1 + 1.4) = 547\ fs$$

$$L_{crit} = \sqrt{\frac{547}{0.38(0.18)(3.0)}} = 51.5\ \mu m$$

$$t_{p,crit} = 2\left(1 + \sqrt{\frac{0.69}{0.38(1 + 1.4)}}\right)(395) = 2.05\ ps$$

$$t_{p(1cm)} = \frac{(10000\ \mu m)}{51.5\ \mu m}(2.05\ ps) = 397\ ps$$

Another way to calculate this value is to use the $t_{p,min}$ equation

$$t_{p,\min(1cm)} = \left(1.38 + 1.02\sqrt{1 + 1.4}\right)(10000\ um) \times \sqrt{(548\ \Omega - \mu m)(0.61\ fF/\mu m)(0.18\ fF/\mu m)(3.0\ \Omega/\mu m)} = 397\ ps$$

Problem 3)

Much of this solution is similar to the Homework 2 solution. Here is the top-level makefile:

Makefile

```
.PHONY: synth report

DESIGN=CORTEXM0DS

UTIL=0.5
MAXLYR=MSMG5
MAXTRANS=40
CLKUNCERT=20

report: pnr
        python parse_reports.py $(UTIL) $(MAXLYR) $(MAXTRANS) $(CLKUNCERT)

pnr: synth
        cd icc2rm && $(MAKE) DESIGN=$(DESIGN) clean
        python set_constraints.py $(UTIL) $(MAXLYR) $(MAXTRANS)
$(CLKUNCERT)
        $(MAKE) -C icc2rm route_opt

synth:
        $(MAKE) -C dcrm

setup:
        echo
date,tgt_util,tgt_max_layer,tgt_max_trans,clk_uncert,route_opt_wnhs,route_o
pt_tnhs,route_opt_nhve,route_opt_max_trans,route_opt_ntv > results.csv

clean:
        cd dcrm && $(MAKE) DESIGN=$(DESIGN) clean
        cd icc2rm && $(MAKE) clean
```

To make this flow work, a template directory was created that included the original files for clock_opt_cts.tcl, floorplan.tcl, icc2_common_setup.tcl, and settings.place_opt.tcl. The set_constraints.py script modifies these files in the flow with the UTIL, MAXLYR, MAXTRANS, and CLKUNCERT variables in the Makefile. Then the parse_reports.py script captures the result. Here are the python scripts:

set_constraints.py

```
import re, sys

util=sys.argv[1]
max_lyr=sys.argv[2]
max_trans=sys.argv[3]
clk_uncert=sys.argv[4]


src=open('template/floorplan.tcl')
dest=open('icc2rm/rm_setup/floorplan.tcl','w')
for line in src:
  m=re.search(r'^set CORE_UTILIZATION',line)
  if m:
    dest.write('set CORE_UTILIZATION '+util+'\n')
  else:
    dest.write(line)
src.close()
dest.close()

src=open('template/icc2_common_setup.tcl')
dest=open('icc2rm/rm_setup/icc2_common_setup.tcl','w')
for line in src:
  m=re.search(r'^set MAX_ROUTING_LAYER',line)
  if m:
    dest.write('set MAX_ROUTING_LAYER "'+max_lyr+'" ;\n')
  else:
    dest.write(line)
src.close()
dest.close()

src=open('template/settings.place_opt.tcl')
dest=open('icc2rm/rm_icc2_pnr_scripts/settings.place_opt.tcl','w')
for line in src:
  m=re.search(r'^  set_max_transition',line)
  if m:
    dest.write('  set_max_transition -clock_path '+max_trans+' [get_clocks
-mode $m] -scenarios [get_scenarios -mode $m]\n')
  else:
    dest.write(line)
src.close()
dest.close()

src=open('template/clock_opt_cts.tcl')
dest=open('icc2rm/rm_icc2_pnr_scripts/clock_opt_cts.tcl','w')
for line in src:
  m=re.search(r'^    set_clock_uncertainty',line)
  if m:
    dest.write('    set_clock_uncertainty -hold '+clk_uncert+' -from
[get_clocks -mode $mode] -to [get_clocks -mode $mode] -scenarios
[get_scenarios -of $mode]\n')
  else:
    dest.write(line)
src.close()
dest.close()
```

parse_reports.py

```
import re, os, sys

tgt_util=sys.argv[1]
tgt_max_layer=sys.argv[2]
tgt_max_trans=sys.argv[3]
clk_uncert=sys.argv[4]

t1=os.path.getmtime('icc2rm/init_design')
t2=os.path.getmtime('icc2rm/route_opt')
pnr_time=str(t2-t1)


f=open('icc2rm/rpts_icc2/route_opt.report_global_timing')
for line in f:
  m=re.search(r'^WNS\s+([0-9\.\-]+)',line)
  if m:
    route_opt_wnhs=m.group(1)
    continue
  m=re.search(r'^TNS\s+([0-9\.\-]+)',line)
  if m:
    route_opt_tnhs=m.group(1)
    continue
  m=re.search(r'^NUM\s+(\d+)',line)
  if m:
    route_opt_nhve=m.group(1)
    break
f.close()

route_opt_max_trans=None
f=open('icc2rm/rpts_icc2/route_opt.report_clock_timing')
for line in f:
  m=re.search(r'Maximum active transition',line)
  if m:
    line=f.readline()
    m=re.search(r'^\s*\S+\s+([0-9\.]+)',line)
    if m:
      if not route_opt_max_trans or
float(m.group(1))>float(route_opt_max_trans):
        route_opt_max_trans=m.group(1)
      continue
f.close()


f=open('icc2rm/rpts_icc2/route_opt.report_qor')
for line in f:
  m=re.search(r'Max Trans Violations:\s+(\d+)',line)
  if m:
    route_opt_ntv=m.group(1)
    break
f.close()
```

parse_reports.py (continued)

```
f=open('icc2rm/rpts_icc2/route_opt.report_utilization')
for line in f:
  m=re.search(r'Utilization Ratio:\s+([0-9\.]+)',line)
  if m:
    route_opt_util=m.group(1)
    break
f.close()

f=open('icc2rm/route_opt')
route_opt_date=f.readline().strip()

f=open('results.csv','a')
f.write(route_opt_date+',')
f.write(tgt_util+',')
f.write(tgt_max_layer+',')
f.write(tgt_max_trans+',')
f.write(clk_uncert+',')
f.write(route_opt_wnhs+',')
f.write(route_opt_tnhs+',')
f.write(route_opt_nhve+',')
f.write(route_opt_max_trans+',')
f.write(route_opt_ntv+',')
f.write(route_opt_util+',')
f.write(pnr_time+'\n')
f.close()
```

My results follow on the next page. If you dig through the results, you'll see that the last line shows sufficient hold-margin.

Clock Uncertainty:	13	ps
Worst Negative Hold Slack:	-0.76	ps
Max Clock Rise-Time:	11.46	ps

(Clock Uncertainty + Worst Negative Hold Slack) >= Max Clock Rise-Time

(13 – 0.76)= 12.24 >= 11.46 (Constraint met)

results.csv

```
date,tgt_util,tgt_max_layer,tgt_max_trans,clk_uncert,route_opt_wnhs,route_opt_tnhs,route_opt_nhve,
route_opt_max_trans,route_opt_ntv,route_opt_util,pnr_time
Mon Sep 16 12:44:17 2019,0.5,MINT5,500,20,-46.78,-60.48,58,142.23,0
Mon Sep 16 14:22:19 2019,0.5,MSMG5,40,40,-34.70,-4892.21,463,39.39,1,0.8124,586.1399998664856
Mon Sep 16 14:58:06 2019,0.5,MSMG5,40,20,-1.00,-5.32,51,39.69,0,0.6164,455.428719997406
Mon Sep 16 15:09:59 2019,0.5,MSMG5,38,20,-3.87,-8.47,47,37.08,0,0.6183,454.6387565135956
Mon Sep 16 15:18:51 2019,0.5,MSMG5,39,20,-0.32,-2.19,35,37.52,1,0.6208,461.635769367218
Mon Sep 16 15:36:04 2019,0.3,MSMG5,40,40,-54.41,-1232.83,169,40.59,4,0.5227,582.0779469013214
Mon Sep 16 15:48:36 2019,0.3,MSMG5,20,20,-0.74,-2.74,36,20.54,6,0.3779,477.23577427864075
Mon Sep 16 16:05:48 2019,0.5,MSMG5,20,20,-9.86,-22.03,45,21.15,7,0.6355,483.3797369003296
Mon Sep 16 16:33:09 2019,0.5,MSMG5,19,20,-3.15,-9.99,46,19.44,5,0.6274,474.9427659511566
Mon Sep 16 17:54:31 2019,0.5,MSMG5,18,20,-5.27,-15.74,28,18.69,6,0.6336,484.8107933998108
Mon Sep 16 18:20:21 2019,0.3,MSMG5,20,21,-0.61,-2.99,36,20.79,7,0.3874,489.94679522514343
Mon Sep 16 18:36:56 2019,0.3,MINT5,20,21,-0.38,-2.05,26,22.13,4,0.3831,476.5447578430176
Mon Sep 16 18:47:26 2019,0.4,MINT5,20,21,-10.73,-65.36,47,36.60,4,0.5127,468.645708322525
Tue Sep 17 08:34:05 2019,0.5,MINT5,500,20,-3.78,-8.83,52,142.10,0,0.6383,452.1167345046997
Tue Sep 17 12:40:44 2019,0.3,MSMG5,20,21,-0.65,-2.71,38,19.17,8,0.3876,818.8383114337921
Tue Sep 17 17:11:49 2019,0.8,MSMG5,20,21,-40.12,-2052.80,458,26.68,7,0.9662,534.0997250080109
Tue Sep 17 17:27:40 2019,0.7,MSMG5,20,21,-15.97,-410.78,177,21.53,10,0.8923,525.8628268241882
Tue Sep 17 21:46:43 2019,0.65,MSMG5,20,21,-11.06,-214.20,107,20.83,7,0.8347,514.4798805713654
Tue Sep 17 21:55:40 2019,0.65,MSMG5,15,15,-0.36,-1.60,22,16.44,9,0.7559,467.11978912353516
Tue Sep 17 22:22:55 2019,0.75,MSMG5,10,11,-2.35,-5.46,22,10.40,17,0.8508,482.919817447766235
Tue Sep 17 22:34:49 2019,0.75,MSMG5,15,16,-11.88,-171.76,97,20.31,7,0.8913,475.9687979221344
Wed Sep 18 05:50:12 2019,0.85,MINT5,500,20,-66.31,-5045.47,731,125.35,0,0.9842,1001.9458661079407
Wed Sep 18 06:35:00 2019,0.75,MSMG5,10,14,-7.99,-69.30,41,11.77,19,0.8770,490.04782938957214
Wed Sep 18 08:39:39 2019,0.70,MSMG5,10,13,-0.09,-0.49,10,11.98,15,0.8066,490.95982551574707
Wed Sep 18 08:54:04 2019,0.70,MINT5,10,13,-5.50,-6.24,13,14.15,24,0.8044,475.77179408073425
Wed Sep 25 14:42:06 2019,0.3,MSMG5,20,21,-7.52,-64.90,66,22.20,5,0.4069,622.6550123691559
Wed Sep 25 15:12:41 2019,0.7,MSMG5,10,13,-3.30,-4.17,15,11.04,24,0.8144,602.1499588489532
Wed Sep 25 15:25:02 2019,0.7,MSMG5,10,14,-3.28,-6.03,9,11.02,17,0.8317,603.4319517612457
Thu Sep 26 08:24:53 2019,0.7,MSMG5,10,13,-0.76,-1.94,19,11.46,20,0.8054,503.6788082122803
```